NOAA TR NMFS SSRF-675

A UNITED STATES
DEPARTMENT OF
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PUBLICATION

NOAA Technical Report NMFS SSRF-675

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

Proceedings of the International Billfish Symposium Kailua-Kona, Hawaii, 9-12 August 1972 Part 2. Review and Contributed Papers

RICHARD S. SHOMURA and FRANCIS WILLIAMS (Editors)

Seattle, Wa
July 1974

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A Review Of The World Commercial Fisheries For Billfishes

SHOJI UEYANAGI[1]

ABSTRACT

This report gives a general "overview" of the commercial fisheries for billfishes. The present world production of billfishes is approximately 100,000 tons per year, of which more than 90% is taken by the tuna longline fishery. Japan alone produces about 70% of the world's catch of billfishes and is the principal consumer nation of these fish.

Although billfishes account for only about 18% of the longline catches, they are presently of considerable importance, especially among the fishery products utilized in Japan. This report discusses the value and utilization of billfishes in Japan, and describes how billfishes have gained status as a quality fish, commanding prices comparable to the tunas. In addition, the expansion of the longline fishery is described, showing that by 1965 the fishery had covered the entire distributional range of the billfishes. Catch and effort data for billfishes indicate that 1) swordfish is the only species which has shown an increase in landings in recent years, 2) blue marlin landings have decreased in recent years in the South Pacific, Atlantic, and to a slightly lesser degree, also in the Indian Ocean, and 3) the catch of the striped marlin has fluctuated greatly from year to year.

Billfishes[2] have been known to man since ancient times. Bones of billfishes—fragments of vertebrae and spears of sailfish, striped marlin, and swordfish—have been found among relics discovered in a shoreside cave at the tip of the peninsula bordering Tokyo Bay (Kaneko et al., 1958). These remains date back to the Jomon Era, some 3,000 to 4,000 years ago.

Since such ancient times billfishes have been taken in Japanese coastal waters, albeit in small numbers, by harpoon fishing. It was with the development of the tuna longline fishery that these fish have emerged as an important world resource of today's magnitude.

The present world production of billfishes, according to FAO statistics (FAO, 1971), is approximately 100,000 metric tons per year, of which more than 90% is taken by the tuna longline fishery. Japan produces about 70% of the world's catch of billfishes and is the principal consumer nation for these fish.

Japan's average annual total catch of billfishes during 1968-70 amounted to 69,000 tons (Ministry of Agriculture and Forestry, Japan, 1972). Combining the longline catches of tunas and billfishes, the billfish catch comprised 18% of the total landings (Figure 1). The proportion contributed by billfishes is about the same as that of the albacore *(Thunnus alalunga)* and both fall below the catches of yellowfin tuna *(T. albacares)* and bigeye tuna *(T. obesus)*. These statistics suggest that billfishes are only an incidental by-product of the longline fishery, and to a certain extent, this is true. Nevertheless, billfishes are presently of considerable importance among the fishery products utilized in Japan.

Among the billfishes, the striped marlin and swordfish predominate, each accounting for approximately 30% of the total catch (Figure 2). Blue marlin and black marlin together make up 25% of the landings, and the sailfish, 14%.

VALUE AND UTILIZATION OF BILLFISHES IN JAPAN

Figure 3 shows the average annual prices for billfishes for the 10-year period from 1961 to 1970.

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[1] Far Seas Fisheries Research Laboratory, Shimizu, Japan.

[2] No distinction is made in this report between the different species which may exist in the various oceans, as for example between the Atlantic blue marlin and the Indo-Pacific blue marlin. Only the generally applied common names are used throughout this report.

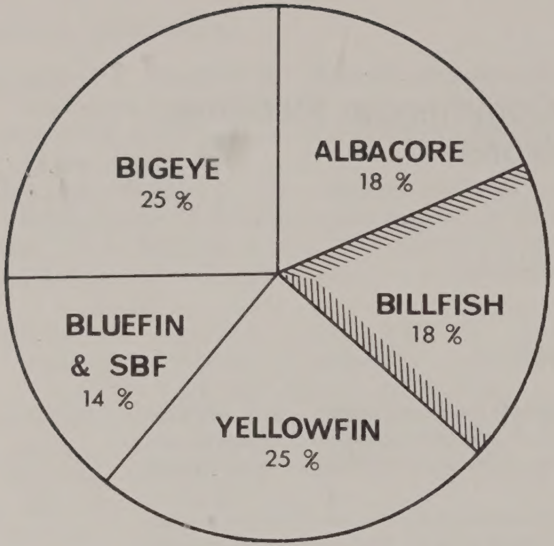

Figure 1.—Average species composition of Japanese tuna fishery catches 1968-70.

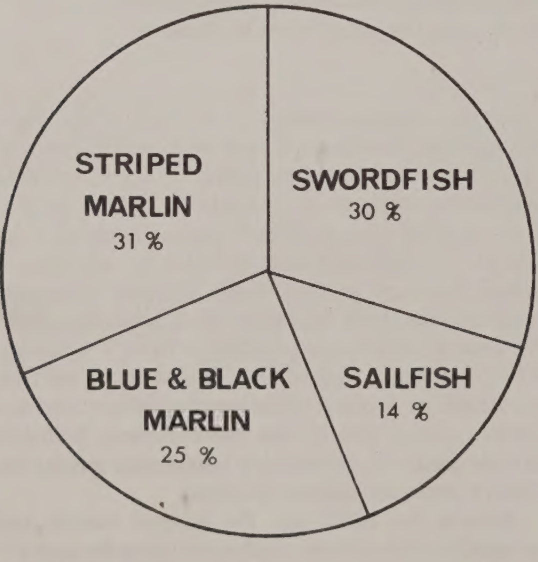

Figure 2.—Species composition of billfish landings in the Japanese tuna fishery, 1968-70.

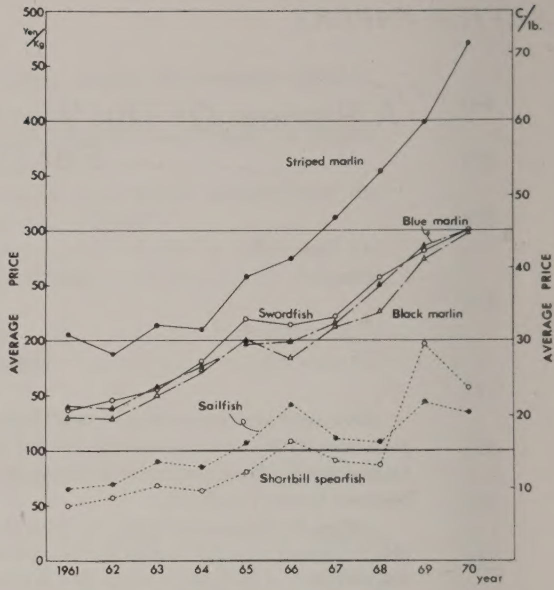

Figure 3.—The average prices of billfishes at the Tokyo fish market, 1961-70.

These are prices at the Tokyo Fish Market where about one-third of all billfishes in Japan are landed. Three classes are evident: the highest priced striped marlin, the intermediate priced blue marlin, black marlin, and swordfish, and the lowest priced sailfish and shortbill spearfish. Billfish prices have generally increased over the years, but the increases were much more rapid after 1966, particularly for striped marlin and, to a slightly lesser degree, for blue marlin, black marlin, and swordfish. The prices for tunas are not shown but for comparative purposes, bluefin tuna *(T. thynnus)* and southern bluefin tuna *(T. maccoyii)* are even more expensive than the striped marlin; bigeye tuna are somewhere between the striped marlin and the intermediate priced group of billfishes, and yellowfin tuna and albacore are between the intermediate and lowest priced groups. In recent years the billfish prices have become comparable with those of tunas because of the way they have come to be used in Japan.

Although the billfishes are not used in canning as are some of the tunas, their uses are very similar to the highly valued tunas: as sashimi,[3] sushi,[4] fish steaks, and as ingredients for fish sausages and hams. Because they are taken along with the tunas in the longline fishery and are utilized in much the same way as the tunas, these fish are frequently referred to in Japan as the "kajiki-maguro" or "billfish tuna."

The billfishes gained status as quality fish in Japan following the 1954 Bikini bomb test. After the test the tunas were found to be contaminated with radioactivity. When this became widely known the market for tunas was seriously affected. In order to avoid a drastic drop in tuna prices, the processors discovered new uses for the fish, including their use in manufacturing tuna sausages and hams. These products gained wide popularity over the next decade. Along with tunas, the blue marlin and black marlin were also utilized in this manner. The price of blue marlin and black marlin increased steadily through 1965 when the production of fish sausage and ham reached its peak. The price then leveled off between 1965 and 1967, but began increasing again after 1967. The latter increase was related to new developments in the tuna longline fishery.

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[3] Thin slices of tuna, billfish or other seafood eaten raw.

[4] Ball of rice marinated in a weak solution of vinegar, salt and sugar; often topped by small amounts of seafood.

Beginning around 1967, Japanese tuna longliners fishing for southern bluefin tuna were equipped with refrigeration facilities which permitted fish to be frozen rapidly to temperatures of −55°C or lower, and also with fishholds capable of holding fish at temperatures below −40°C. Fish could then be brought back to Japan from distant grounds in excellent condition. Billfishes brought back under such refrigeration were acceptable as sashimi and fish steaks. This new use gained wide popularity and presently is the common form of utilization in Japan. The striped marlin is particularly valued as sashimi and, like the southern bluefin tuna, commands very high prices.

In general, billfishes larger than about 30 kg are used as sashimi. One of the advantages of billfish flesh is that it does not undergo as much color change as that of tunas. It can thus withstand longer periods of transportation and possesses a longer market shelf-life than tuna.

The principal utilization of billfishes, by species, is as follows:

Striped marlin	—virtually all used as sashimi; remainder in sushi.
Blue and black marlins	—virtually all as sashimi.
Swordfish	—steak, sashimi.
Sailfish	—those over 30 kg as sashimi; others in sausages and hams.
Shortbill spearfish	—fillets for use as steak; broiled or baked.

Of all the billfishes landed at the Tokyo Fish Market, roughly one-half are consumed in the city of Tokyo; the remainder is distributed throughout Japan from Hokkaido to Kyushu.[5]

DEVELOPMENT OF THE LONGLINE FISHERY

As described earlier, virtually all of the commercial catches of billfishes are made by the longline method; only a negligible amount of surface-swimming billfish is taken by the harpoon fishery. The longline gear seem most effective in capturing the deep-swimming billfishes.

The regular longline operation involves a set of gear whose mainline extends over a distance of 25-75 km at the surface of the ocean. Branch lines with baited hooks, numbering about 2,000 per set, hang vertically from the mainline, which is suspended at the surface by float lines and buoys. The baited hooks usually hang at depths of 100-150 m. The gear is set very early in the morning and its retrieval, which begins around noon, takes many hours, with completion frequently well past midnight.

There is a special type of "night longlining" which is aimed principally at catching swordfish. This is, as the name implies, an operation in which the gear is set at night. Compared to the typical tuna longline, the night longline gear is set to fish much shallower by the use of additional floats and shorter gear elements. Another difference is in the use of squid as bait rather than the saury, *Cololabis saira,* which is preferred for regular longlining.

Longlining has the advantage of not having to rely on live bait. This gives the fishery a great deal of mobility. The tuna longliners can roam the world's oceans, fishing distant waters in pursuit of the desired species of fish. Another advantage is that there is a minimum amount of gear selectivity, in that small to large fish of various species can be taken by this method.

The longline fishing grounds have rapidly expanded over the years. Although the longline fishery was aimed principally at the various species of tunas, with the expansion of the grounds, more and more billfishes came within range of the fishery. The fishing ground expansion is shown in Figures 4, 5, and 6.

Pacific Ocean

Before 1955 the fishery was centered in the central and western Pacific Ocean (Fig. 4), where it exploited the striped marlin of the northwestern Pacific and the blue marlin in the equatorial region. This fishery also began to catch striped marlin of the southwestern Pacific and the black marlin in the

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[5] Information on value and utilization of billfishes was provided by Mr. Hiroyo Koami of the Tsukiji Fish Market Co. Ltd., Tokyo.

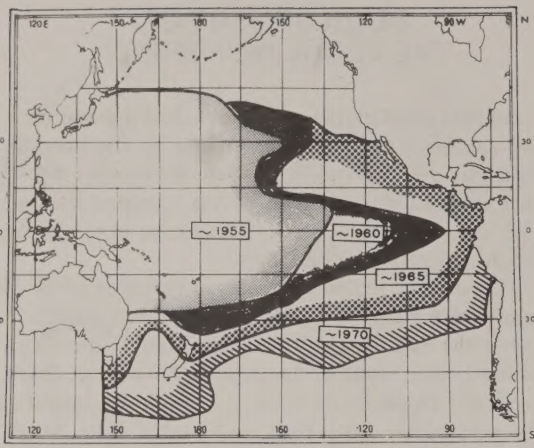

Figure 4.—The expansion of Japanese longline fishing grounds in the Pacific Ocean shown at 5-year intervals (from Kume, in press).

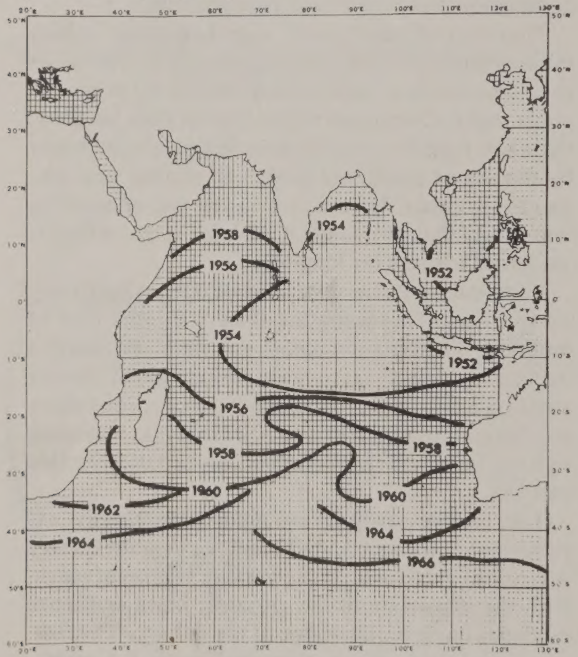

Figure 5.—The expansion of Japanese longline fishing grounds in the Indian Ocean (adapted from Kikawa et al., 1969).

Coral Sea. In the next 5-year period, 1956-60, the fishing grounds expanded eastward along the equator to near the Central American coast, with yellowfin tuna and bigeye tuna as the principal species being taken. The fishery also extended the bigeye tuna fishing grounds in waters northeast of Hawaii and at this time began taking striped marlin of the northeastern Pacific.

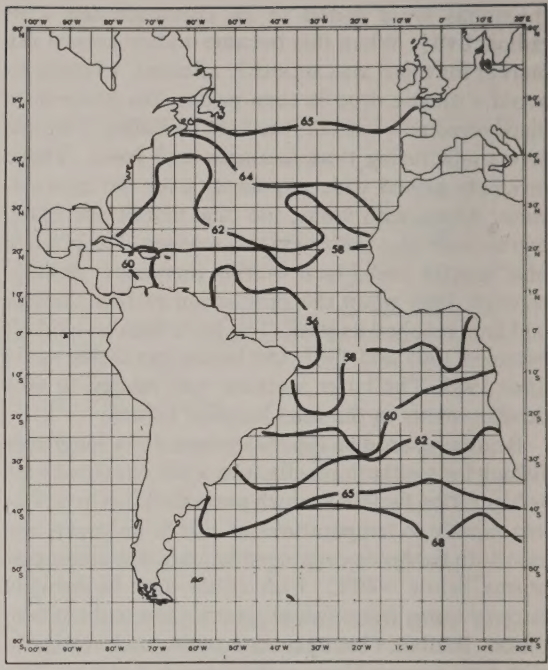

Figure 6.—The expansion of Japanese longline fishing grounds in the Atlantic Ocean.

Between 1961 and 1965, the fishing grounds moved farther eastward into the American coastal waters. There was also an expansion in the northeastern and southern directions. This expansion resulted in complete coverage of the distribution of striped marlin in the Pacific Ocean. The blue marlin of the southeastern Pacific, along lat. 20°S and between long. 130° and 150°W also began to be taken. The expansion of grounds after 1965 was largely for southern bluefin tuna in the higher latitudes of the South Pacific.

As for future developments in the Pacific, we may be able to look forward to further developments of the swordfish resources along the coasts of South America and Australia.

Indian Ocean

The expansion of the longline fishing grounds in the Indian Ocean is shown by 2-year intervals (Fig. 5). In 1952 the yellowfin tuna grounds around the Lesser Sunda Islands began to expand westward and by 1956 had reached the African coast. By 1958 the

Indian Ocean to the north of lat. 20°S was virtually covered. Since then, the grounds have spread southward, with albacore in waters off Madagascar as the primary objective. In the eastern Indian Ocean the fishery spread southward in pursuit of the southern bluefin tuna, and by 1964, reached lat. 40°S. The distributional range of the several species of billfishes was completely covered at this time. Southerly movements since 1964 were related to southern bluefin tuna exclusively, and not to billfishes.

Atlantic Ocean

The longline fishery in the Atlantic Ocean began in 1956 (Fig. 6) in waters north of Brazil for yellowfin tuna. Within 2 or 3 years it expanded in equatorial waters to the African coast.

Since 1958 the fishery has spread both to the north and south in pursuit of albacore, and by 1965, had covered the area between lat. 45°N and 45°S. It then became continuous with the Indian Ocean grounds by moving around the southern tip of Africa. In the Atlantic, as in the Pacific and Indian Oceans, the fishing grounds cover the entire distributional range of the billfishes.

In summary, it is seen that by 1965 virtually the entire distributional range of billfishes in the Pacific, Indian, and Atlantic Oceans had been covered by the Japanese longline fishery. In this regard, it can be said that with this coverage it has become possible to view the entire distributional picture of the billfishes through the activities of the longline vessels.

THE DISTRIBUTION OF FISHING EFFORT AND THE CATCH OF BILLFISHES BY THE JAPANESE LONGLINE FISHERY[6]

The distribution of fishing effort of the Japanese longline fishery, in terms of numbers of hooks fished, has been plotted for 1970 by 5° quadrangles (Fig. 7). It is seen that fishing effort was particularly large in such areas as the northwestern Pacific, equatorial Pacific, and certain areas around lat. 40°S, especially south of Australia and around New Zealand. If fishing effort of the vessels from Taiwan and South Korea is included, it will show considerable effort in all oceans, particularly in the equatorial regions.

Although the fishing effort is aimed principally at the tuna resources, there are areas where the effort is primarily for certain species of billfishes.

Fishing effort for albacore, bigeye tuna, striped marlin and swordfish is concentrated in the northwestern Pacific, that for bigeye tuna and striped marlin in the northeastern Pacific. In the central equatorial Pacific region effort is concentrated on yellowfin tuna and bigeye tuna as well as the blue marlin. Bigeye tuna and striped marlin are the principal species sought in the eastern equatorial region. In Mexican waters the effort is exclusively for striped marlin, and such exclusive fishing effort for billfish is seen nowhere else, except for sailfish in the coastal waters of Central America.

In waters south of Australia fishing effort is concentrated on the southern bluefin tuna.

The 1970 catch of striped marlin (Fig. 8), and blue marlin (Fig. 9), in numbers, is shown by 5° quadrangles. The striped marlin catches are relatively high in the central North Pacific and in the eastern Pacific. Other areas of good catches are in the waters east of Australia, northwest of Australia, Bay of Bengal, and the Arabian Sea. There are also some good catches in the western North Pacific.

As for the blue marlin (Fig. 9), the areas of good catches range from the western equatorial to the central equatorial Pacific Ocean.

THE HARPOON FISHERY

Although the harpoon fishery primarily seeks billfishes, the catch is very small compared to that made by the longline fishery. The catch of Japan's harpoon fishery in 1970 was approximately 3,000 tons of billfishes, or less than 5% of the total Japanese billfish landings.

The vessels of the harpoon fishery are of wooden construction and range in size from about 10 to 40 tons. All catches made by these vessels are iced for delivery to the markets. Because of shorter trips, the fish are relatively fresh when landed and thus command good prices at the market. The fish are suitable for use as sashimi.

The harpoon fishery operates in coastal waters, and in Japan, takes largely the striped marlin and swordfish. The fishing grounds are located in waters off Sanriku (northeastern Honshu), around Izu Island, and in the East China Sea. The seasons are from July through October in the Sanriku grounds,

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[6] Data source from Fisheries Agency (of Japan), 1972.

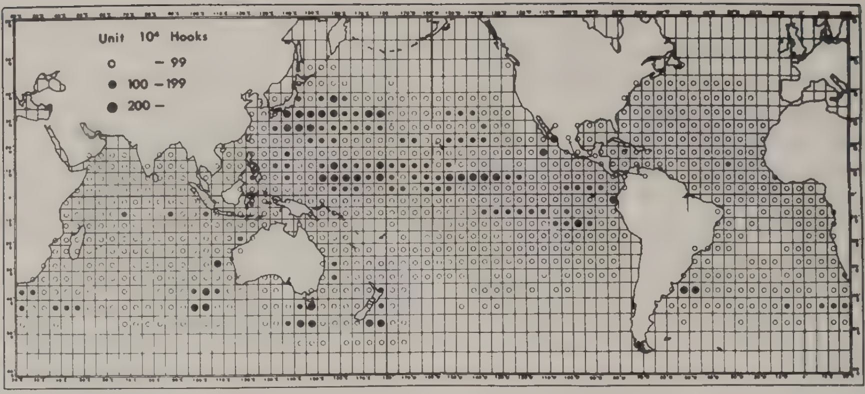
Unit 10⁴ Hooks
○ - 99
● 100 - 199
● 200 -

Figure 7.—The estimated total fishing effort (number of hooks per unit area) in the Japanese longline fishery during 1970 (from Fisheries Agency of Japan, 1972).

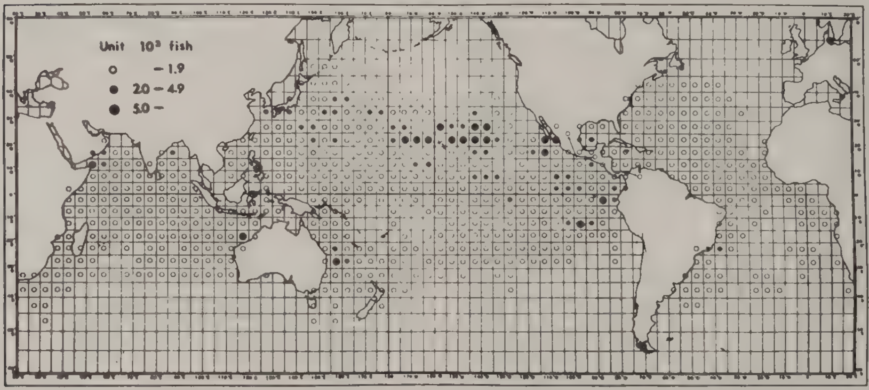
Unit 10³ fish
○ - 1.9
● 2.0 - 4.9
● 5.0 -

Figure 8.—The catch of striped marlin shown as numbers of fish taken per unit area during 1970 (from Fisheries Agency of Japan, 1972).

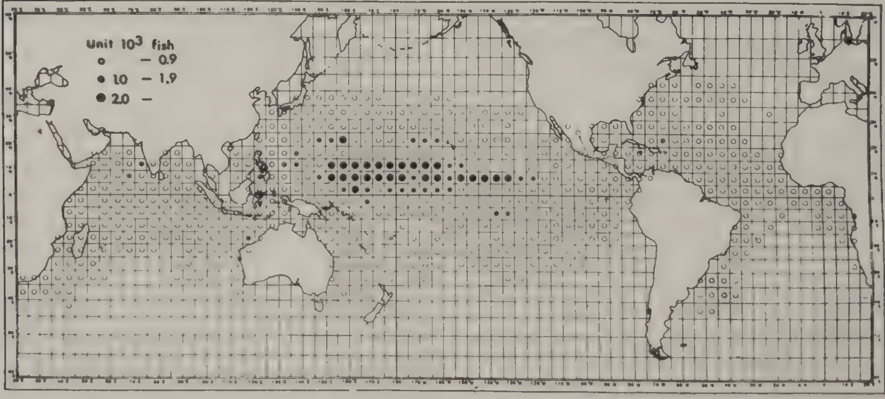
Unit 10³ fish
○ - 0.9
● 1.0 - 1.9
● 2.0 -

Figure 9.—The catch of blue marlin shown as numbers of fish taken per unit area during 1970 (from Fisheries Agency of Japan, 1972).

February through April off Izu Island, and from December to February in the East China Sea. Fishing conditions seem to be greatly affected by the position of the Kuroshio Current in coastal waters.

RECENT STATUS OF BILLFISH PRODUCTION

The average annual world catch of billfishes during 1968-70 amounted to approximately 103,000 tons (FAO, 1971). Of this total, swordfish comprised roughly 30%, striped marlin 25%, and blue and black marlins, combined, 25% (Fig. 10).

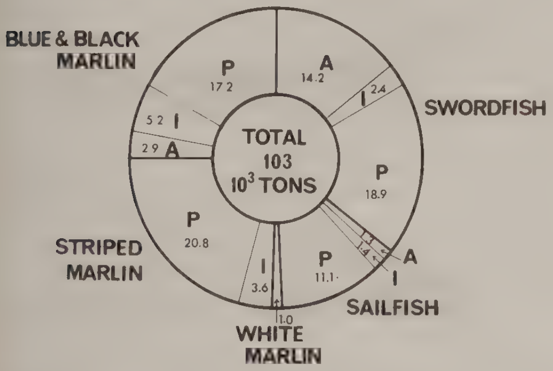

Figure 10.—Average percentage composition of world billfish catch, by species and by ocean, 1968-70. (I—Indian Ocean, P—Pacific Ocean, and A—Atlantic Ocean.)

Japan produced approximately 55% (about 20,000 tons) of the total swordfish landings. Canada, Spain, Taiwan, Peru, and Italy each landed from 1,000 to 5,000 tons, and together with Japan accounted for more than 90% of the total catch.

Excluding swordfish, the combined longline fisheries of Japan and Taiwan produced 94% of the total landings. The Japanese longline fishery alone was responsible for about 75% of the total world catch of these several species.

The 1961-70 world catches of billfishes (all species combined) and of swordfish alone, are shown in Figure 11. With the expansion of the Japanese longline fishing grounds, the total catch of billfishes increased from about 80,000 tons in 1961 to a peak of about 110,000 tons in 1964-65. This peak corresponded to the time when the fishery first covered the entire distributional range of the billfishes in the Pacific, Indian, and Atlantic Oceans.

Total annual landings have slightly decreased since 1966, leveling off at around 100,000 to 105,000 tons. The swordfish, which makes up about 30% of the billfish catches, did not show a similar decrease after 1966. Rather, the catches tended to increase gradually.

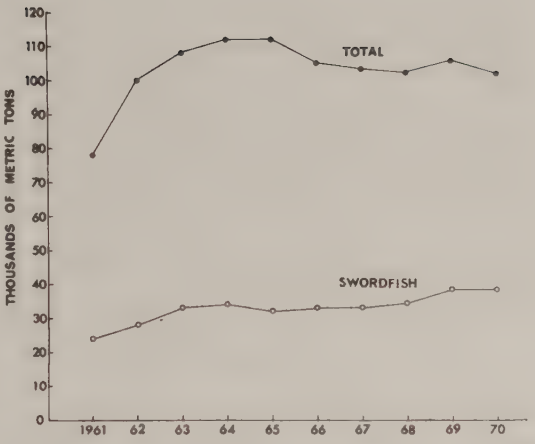

Figure 11.—Annual world catch of billfishes (all species combined) and of swordfish (exclusively), 1961-70.

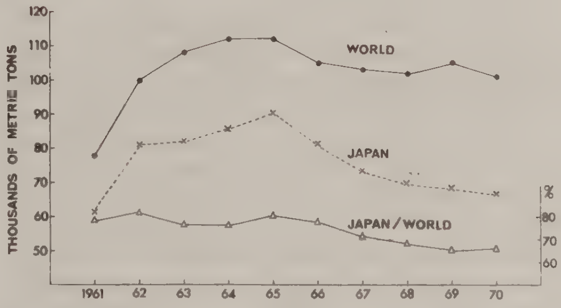

Figure 12.—Annual world production and Japanese production of billfishes, 1961-70.

In Figure 12 is shown Japan's catch of billfishes in relation to the world catch for the years 1961-70. Japan's catch began increasing in 1961 and reached a peak of 90,000 tons in 1965. Thereafter, the catches decreased yearly. This decrease was reflected in the trend in world catch. However, the decrease after 1967 in the Japanese catch was partially offset by an increase in landings of the longliners from Taiwan.

The decrease in billfish landings by the Japanese vessels after 1967 was caused by a combination of reduced fishing effort in the Atlantic Ocean and the shifting of vessels into the Indian Ocean. Here a large part of the effort went to fishing southern

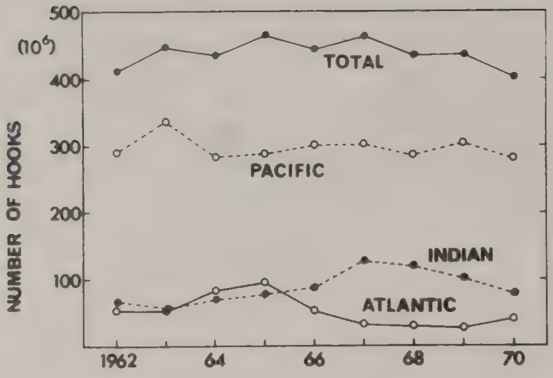

Figure 13.—Annual fishing effort (number of hooks), by ocean, of the Japanese tuna longline fishery, 1962-70.

bluefin tuna in the higher latitudinal waters where billfishes are generally not found.

The general leveling of the yield of billfishes following the full coverage of the billfish distributional range by the longline fishery may be indicative, as in the case of the larger tunas, that some of these species are already being fished near the level of maximum sustainable yield.

The relationship between catch and effort for the various species, based on Japanese longline data (Fisheries Agency of Japan, 1972), is next examined. The annual Japanese longline fishing effort in terms of numbers of hooks fished, for the years 1962-70, is shown in Figure 13. The total fishing effort for all oceans remained relatively stable at around 450 million hooks. This is the result of the Japanese fishery policy (in effect since 1963) of controlling fleet size in order to effect the rational utilization of the tuna resources and to maintain the tuna fishing industry on a sound foundation.

Of the total 450 million hooks, roughly two-thirds of the effort, or 300 million hooks, was expended in the Pacific Ocean. This level of effort has remained relatively steady in the Pacific since 1964.

The fishing effort was about the same in the Indian and Atlantic Oceans in 1963, but became slightly greater in the Atlantic in 1964-65. Since 1965 it has been considerably greater in the Indian Ocean. This shift in effort was due to a decrease in catch in the Atlantic Ocean and the subsequent movement of vessels into the southern bluefin tuna grounds of the Indian Ocean. Since 1968 there appeared to be a trend toward decreasing effort in the Indian Ocean and increasing effort in the Atlantic Ocean.

The catch of billfishes, by species, by the Japanese longline fishery from 1962 to 1970 is shown in Figures 14, 15, and 16.

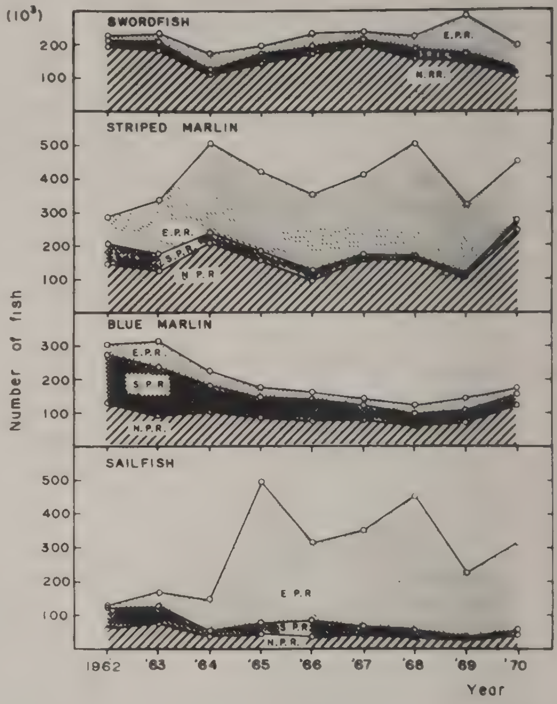

Figure 14.—Annual catch, in numbers, of the four major billfish species in the Pacific Ocean, 1962-70 (from Kume, in press). EPR, SPR, and NPR denote eastern Pacific region (east of long. 130°W), South Pacific region (south of lat. 5°N, west of long. 130°W), respectively.

Pacific Ocean

The Pacific Ocean was subdivided into the following three regions (Fig. 14): the eastern Pacific region (east of long. 130°W), the North Pacific region (north of lat. 5°N, west of long. 130°W), and the South Pacific region (south of lat. 5°N, west of long. 130°W).

Swordfish—The yearly catches of swordfish varied little, numbering about 200,000 per year on a Pacific-wide basis. However, taken by regions, a slight decrease was noted in the North Pacific region, particularly after 1967. The catch in the eastern Pacific region increased after 1968 as a result of fishing in swordfish waters of Baja California and Ecuador.

Striped marlin—Since 1963 the eastern Pacific region has been the most productive of striped marlin fishing grounds, followed by the North Pacific region. The catch in the North Pacific region has fluctuated from year to year and the 1970 catch in that region was particularly high.

Blue marlin—There has been a trend toward decreased landings of blue marlin between 1963 and 1968. This trend was particularly marked in the South Pacific region. The increased catches in the North Pacific region in 1969 and 1970 were responsible for reversing the downward trend.

Sailfish—A negligible amount of shortbill spearfish is included in the catch statistics for this category. Since 1965, the catches of sailfish have largely been made in the eastern Pacific region. The landings have been marked with considerable fluctuations from year to year.

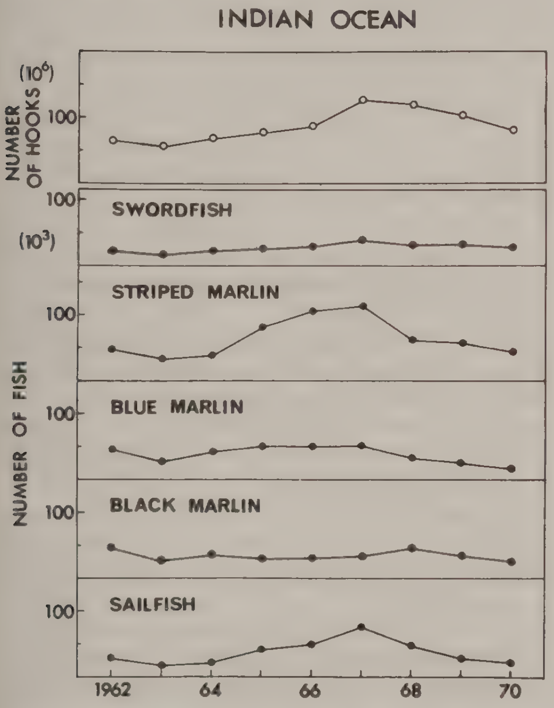

Figure 15.—Annual total longline fishing effort (upper panel) and annual catch of billfishes (lower panel) from the Indian Ocean, 1962-70.

Indian Ocean

The catch and effort data of billfishes from the Indian Ocean are shown in Figure 15.

Swordfish—The slight increase in swordfish landings after 1966 seems to reflect increased fishing effort.

Striped marlin—The catches have varied considerably but were relatively high during 1965-67.

Blue marlin—The catch of blue marlin tended to correspond with the amount of fishing effort expended until about 1966. Beginning in 1967, the catch decreased in spite of increased fishing effort.

Black marlin—The average annual catch was approximately 36,000 fish. The catches remained relatively steady from year to year.

Sailfish—The catch of sailfish varied considerably from year to year and resembled the catch trend for the striped marlin.

Atlantic Ocean

The catch and effort data of billfishes from the Atlantic Ocean are shown in Figure 16.

Swordfish—The catches generally corresponded with fishing effort through 1968 but increased in 1969

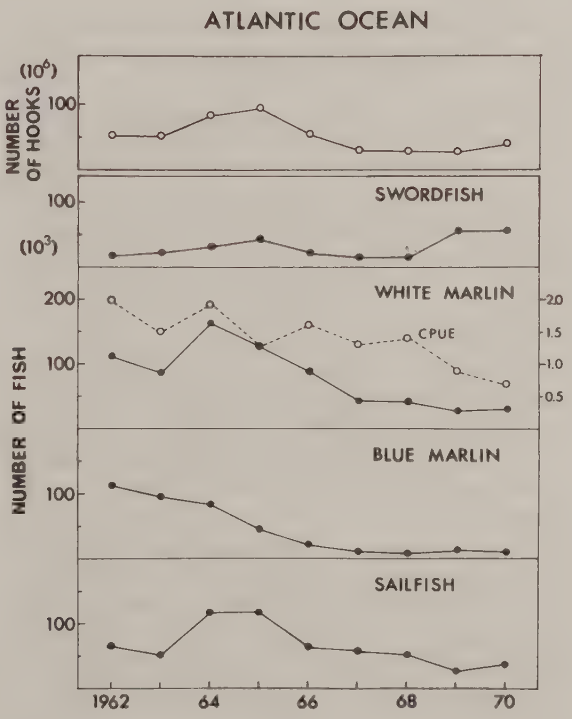

Figure 16.—Annual total longline fishing effort (upper panel) and annual catch of billfishes (lower panel) from the Atlantic Ocean, 1962-70. Catch per unit effort (CPUE) is shown for white marlin only.

and 1970 in spite of relatively low effort. This increase was due to good catches made in higher latitudinal waters off the South American coast.

White marlin—The catch of white marlin decreased markedly after 1964. The average density, shown by the catch per unit effort, also decreased over the years.

Blue marlin—The blue marlin showed a clearly downward trend since 1962. The average density of this species after 1965 fell to about one-fourth the level in 1962 (Ueyanagi et al., 1970).

Sailfish—The catch statistics also included some longbill spearfish in this category. The yearly fluctuations in catches have generally corresponded to the Atlantic Ocean fishing effort.

Some significant observations from the above are: 1) swordfish is the only species which has shown an increase in the landings in recent years, 2) blue marlin landings have decreased annually in the South Pacific, Atlantic, and to a slightly lesser degree, also in the Indian Ocean, and 3) the catch of the striped marlin has fluctuated greatly from year to year.

FUTURE PROBLEMS IN BILLFISH RESEARCH

The above-mentioned views on the trends of catch for billfish species in relation to effort are based on total hooks and not on the standardized fishing efforts for the species. For this reason, the status of billfish resources might not be reflected accurately. Nevertheless, the catch trends suggest that some species or stocks of billfishes are being rather heavily fished. It is imperative that stock assessment studies be pursued vigorously on these species.

Other than in the eastern Pacific striped marlin fishing grounds, the billfishes are being taken by the longline fishery incidental to the major tuna species. The fishery shifts according to the distribution of the tunas, and for this reason, it is difficult to compile adequate data on billfishes for analysis of the relationship between catch and effort. Since the longline fisheries of Taiwan and Korea are becoming increasingly significant, it is necessary that catch and effort data from these countries be used along with Japanese data for reliable stock assessment studies. In other words, it is important to compile adequate data on catch and effort for these fish, and also, along with these studies, to clarify the population structure of the various species.

At this point, we might emphasize the importance of studying the population structure of the striped marlin, not only because of its dominance in the commercial landings, but also because of its importance in the sport fishery (FAO, 1972). Furthermore, from the biological point of view, several characteristics encourage further study of this species:

1. The large fluctuations in striped marlin landings in the Pacific and Indian Oceans are believed to be due to certain biological characteristics of the species. For example, from studies of the striped marlin in the northwestern Pacific it was found that the average density tended to undergo biennial fluctuations, probably caused by variations in recruitment. A detailed study of such fluctuations can be expected to contribute towards the understanding of the population structure of the species.

2. The distribution of the striped marlin in the Pacific takes on a horseshoe-shaped pattern, circumscribing the tropical areas. This species, however, is distributed both in the tropical and subtropical waters of the Indian Ocean. Thus, while most species of tuna and billfishes are distributed in the same pattern in the major oceans, the striped marlin seems to be an exception.

The spawning areas are centered in subtropical waters of both the North and South Pacific while in the Indian Ocean, spawning seems to be centered in tropical waters (Fig. 17).

3. The differences in the distribution of the adult striped marlin and in their spawning areas in the Pacific and Indian Oceans may be indicative of a process of speciation. This presents an interesting problem in relation to studies on the billfish phylogeny and hierarchy.

For population identification, various approaches such as tagging, morphometrics, genetics, and parasitology may be necessary. It is also important to consider different and new approaches to this problem. I discuss in greater detail in a separate paper at this symposium (Ueyanagi, 1974) the possibility that studies in larval morphology can contribute towards population identification.

Because of the importance of the tuna fishery, scientists have devoted their attention to the studies of tunas in the past 10 years. Consequently, research on billfishes is lagging considerably behind the tunas. This International Billfish Symposium, however, may well be the turning point and we may be able to look forward to increased effort towards the study of billfishes.

The billfishes, needless to say, are important both to the commercial and sport fisheries. We must ac-

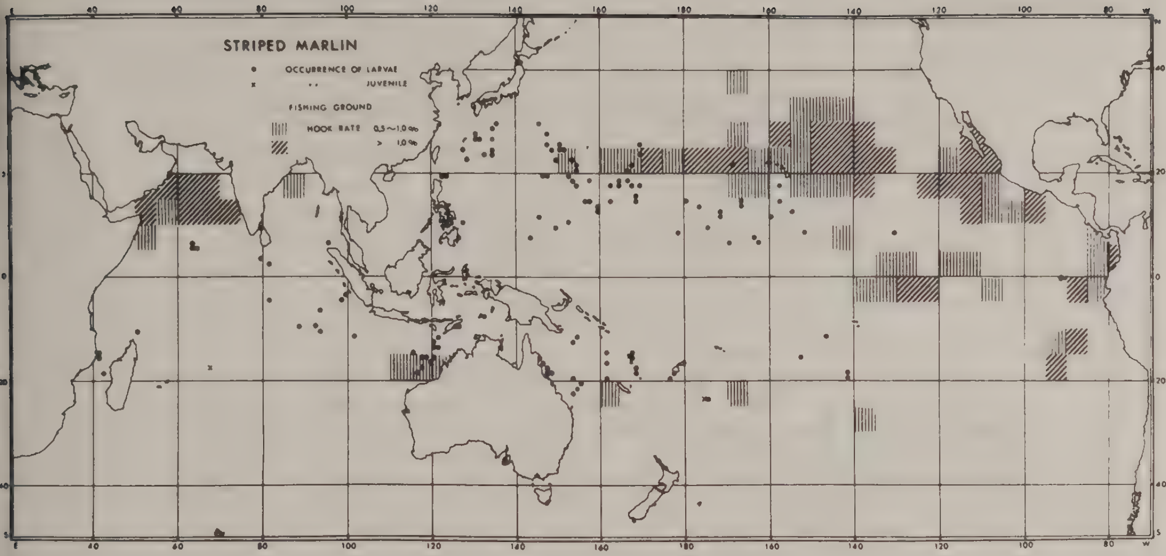

Figure 17.—Larval distribution and fishing grounds for striped marlin in the Pacific and Indian Oceans.

quire a thorough knowledge of these fish if we are to assure their continued and rational utilization. To attain this goal, mutual cooperation between commercial and sport fishing interests is necessary.

Finally, in closing, I would like to express my hope that this international gathering will serve to deepen the understanding between scientists and fishermen of the various nations regarding the future of the billfish resources, and will bring about cooperative effort to advance research as well as fishery endeavors to our mutual advantage.

ACKNOWLEDGMENT

I sincerely thank Tamio Otsu of the National Marine Fisheries Service, Honolulu, who helped me with the English translation and critical review of the manuscript. I am also grateful to Hiroyo Koami of the Tsukiji Fish Market Co. Ltd. who provided me with the information on value and utilization of billfishes.

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A Review of the World Sport Fishery for Billfishes (Istiophoridae and Xiphiidae)[1]

DONALD P. DE SYLVA[2]

ABSTRACT

Sport fishing is conducted for billfishes (Istiophoridae and Xiphiidae) in nearly all warm oceans, primarily in tropical and subtropical seas. In probable order of descending catch rate, the principal species caught by anglers are sailfish, white marlin, blue marlin, striped marlin, black marlin, swordfish, and longbill spearfish; the shortbill and Mediterranean spearfishes are rarely taken by anglers. Important sport fisheries are presently concentrated from Massachusetts to North Carolina and about Bermuda, southeastern Florida, the northern and northeastern Gulf of Mexico, the Bahamas, the larger islands of the Caribbean, Venezuela, the eastern tropical Pacific between southern California and Chile, Hawaii, New Zealand and eastern Australia, Kenya to Cape Town, South Africa, Ivory Coast to Senegal, West Africa, and off Portugal, Spain, and Italy.

In some regions maximum angling effort coincides with maximum availability of billfish, while in others, especially in the western North Atlantic, maximum angling pressure is correlated with angling tournaments which in turn relate to summer vacations of tourists and the tendency of most anglers to fish only during the day and when the weather is favorable. Angling for billfish during the "off-season" may well produce good results in areas which usually are heavily fished only at certain periods. New billfishing regions probably can be developed, but this requires the assistance of local governments to provide or ensure adequate sportfishing vessels, docks, bait, and, especially, qualified captains and crews.

Because of the relative inefficiency of the gear used by anglers to catch billfish, it is unlikely that angling can deplete the billfish stocks, other factors such as natural environmental fluctuations, pollution, or commercial fishing being equal. There is evidence that commercial fishing in the eastern Pacific is affecting the sport catches of sailfish and striped marlin. Based on commercial catch data, the mean size of sailfish and striped marlin and their hooking rate have decreased. In the Caribbean the catch rate of blue marlin and white marlin by commercial fishermen has decreased; this phenomenon may be attributed to heavy commercial fishing pressure from longline fleets.

The economic value of the billfish sport fishery is extremely high to local communities which support angling activities. In spite of some aesthetic feelings which promote releasing of billfish which are not tagged, it would appear that catches by anglers could be retained for human consumption without seriously depleting the stocks, thus further contributing to local economy.

Sport fishing for billfishes poses special problems because of the complexity, expense, expertise required, and lack of basic information on the fisheries and the fishermen. Possible solutions to these are discussed.

Since the end of World War II, the sport fishery for billfishes (Istiophoridae and Xiphiidae) has developed markedly geographically and in effort expended. Better and cheaper air travel, fast sportfishing boats equipped with excellent tackle and fish-finding devices, and increased leisure time in many countries have enabled the average man to make dreams of catching giant marlin—which he once could only read about in magazines such as *Field and Stream*—become a reality. The increase in size and scope of the billfish sportfishing industry, for it *has* become a virtual industry, has more than paralleled the expansion of the commercial fishery for billfishes on the high seas of the world. Each interest is legitimate, but because both industries are seeking the same resource, including the ecologically and economically related tunas, legitimate concern is expressed by each interest that his own kind of fishing may eventually be excluded.

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An article in the *New York Times*, during November, 1969, revealed a brief economic survey carried out by one of their reporters prior to the U. S. Atlantic Tuna Tournament. Tournament anglers were polled prior to the tournament concerning expenses incurred in catching billfish and tunas, including the money spent when fish were *not* caught. Perhaps not surprisingly, they reported that the average cost to the angler to catch a sailfish was $4,000, a blue marlin $10,000, and a swordfish $20,000. One may argue that these figures may be too high or too low; nevertheless, they indicate the economic importance of the sport fishery for billfishes.

It is especially noteworthy that both the commercial and sport fisheries are based on biological resources about which we know very little, nor do we understand much about the environment of billfishes. They spend their life cycle on the "high seas," where their breeding and feeding must be studied from inference, based on examination of dead specimens. We can generally only speculate on their habits and attempt to forecast what oceanographic conditions may be associated with their movements; to attempt to maintain and study a 200-kg marlin in a tank is presumably beyond the technological capabilities of even the most clever aquarists.

A preliminary bibliography of the billfishes (de Sylva and Howard, MS)[3] contains over 2,000 references, yet even if we use the sum total of knowledge of these references, which dates back over 400 years, we really have very little comprehensive knowledge about the habits of the billfishes. We must be especially grateful to the Japanese commercial fishermen and scientists working with them, as well as fishermen and scientists of other countries, who have so enriched the literature with their study of thousands of billfishes from all over the world. To those billfish anglers who decry the large number of billfishes caught by Japanese longlines, the following quote from the late Colonel John K. Howard (*in* Howard and Ueyanagi, 1965:4) seems in order: "In the last analysis, if it were not for the extraordinary foresightedness, initiative, and organizing ability of the great Japanese fishery companies, as well as the energy, high quality of seamanship, and great technical fishing skill of their ships' officers and crews, there would be no catches of istiophorid fishes from all over the world to serve so usefully in this distribution study."

It is difficult to ascertain just how long man has intentionally fished for billfishes for sport, but such recreation is probably a relatively recent product of our age of leisure. Billfishes have been caught for food commercially for centuries, using harpoons, longlines, traps, or nets, but it is only with the relatively recent appearance of multiplying reels, laminated bamboo poles and Fiberglas rods, and light line that man could hope to derive pleasure from fighting a billfish in a reasonably sportsmanlike manner.

In the Pacific, the first billfish to be taken on hook and line was a striped marlin taken in 1903 off Avalon, California (Howard *in* Howard and Ueyanagi, 1965:10). Sport fishing for billfishes could not have been well developed at the turn of the century, for Charles F. Holder, one of the deans of early big game fishing, and founder of the Tuna Club at Avalon, California, in his comprehensive book "Big game fishes of the United States" (Holder, 1903), does not mention swordfish, marlin, or sailfish. It is believed, however, that Holder was also one of the pioneers in the popularization of fishing for sailfish in Florida, probably during the period from 1905 to 1910. Angling for billfish remained the sport of the very wealthy, and it was not followed by many devotees until the 1920's when Ernest Hemingway synonymized billfishing in the Bahamas and off Cuba with gutsy adventure stories. It was also about this time when Zane Grey became enthralled with his angling experiences with giant swordfish and marlin in the Pacific. These narratives certainly must have tingled the hearts of those thousands of snowbound northerners who vicariously sped off to sea to troll for "The Big One."

Up to the time of World War II, billfishing, as well as tuna fishing, grew in popularity, especially off Florida, the Bahamas, and southern California. During this time Hemingway, Tommy Gifford, Van Campen Heilner, Michael Lerner, Kip Farrington, Zane Grey, and John K. Howard were among those pursuing the ocean gamesters with relatively primitive fishing vessels and tackle.

The war found many of the marlin.boats and their skippers tied up in antisubmarine service or Coast Guard patrols. Nevertheless, sport fishing for billfishes, and even marlin tournaments such as at Ocean City, Maryland, continued sporadically because it took more than mines, torpedoes, and gas rationing to deter a true billfish angler. After the war, better and faster sportfishing vessels, electronic navigational and depth-finding gear, and greatly improved tackle, such as Fiberglas rods and monofilament line, improved the efficiency of the billfish and tuna angler and his vessels. With these additions came a new wave of wealthy and mobile anglers to explore untried areas of the world. But such men failed to hold the monopoly on new fishing grounds and big fish because, often to the dismay of established world-record holders, the "little man" with no angling experience, thanks to excellent captains, dedicated mates, and superb tackle and boats, has frequently broken the world's record for billfish. Sport fishing for marlin, sailfish, and swordfish is no longer a rich man's exclusive pastime: it is now within the reach of nearly anyone's budget to spend $100 a day to be reasonably assured of at least *seeing* a billfish. Further the thrill of *hooking* a billfish and watching its acrobatics is virtually unparalleled in the excitement of sport.

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[3] de Sylva, Donald P. and John K. Howard. 1972. A preliminary bibliography of billfishes (Istiophoridae, Xiphiidae, and related fossil families). U.S. National Marine Fisheries Service, July, 1972, 160 pp. Mimeogr.

SPECIES CAUGHT BY ANGLERS

Data on the number of different species of billfishes caught by anglers around the world are virtually non-existent. Individual anglers and captains sometimes maintain logbooks, while tournaments may reveal how many of the different species are taken over a short time span. Probably the best estimates of relative abundance are obtained from taxidermists, because a billfish is considered a highly desirable, spectacular trophy which can be mounted as a memoir to an exciting day. Anglers apparently do not differentiate in their desire to have a large fish mounted in contrast to a small one, in spite of the cost differential, or between a sailfish and a marlin. We may thus assume that taxidermists' records possibly reflect the relative availability of different species of billfish. Invaluable data on size, locality, and date of capture are thus available for scientific studies from taxidermists' records.

Based upon such records and intuition from twenty years of working with billfish and billfish anglers, I suspect that in probable order of descending importance in terms of the number caught (or released), the principal species are: sailfish, *Istiophorus platypterus*[4]; white marlin, *Tetrapturus albidus;* blue marlin, *Makaira nigricans;* striped marlin, *Tetrapturus audax;* black marlin, *Makaira indica;* swordfish, *Xiphias gladius;* and longbill spearfish, *Tetrapturus pfluegeri* (see Robins and de Sylva, 1961 and 1963, for a discussion of recent nomenclature). The shortbill spearfish, *Tetrapturus angustirostris,* from the Indo-Pacific, is largely confined to the high seas. A specimen has been taken from Australia (Goadby, 1970) on hook and line, while it is occasionally taken by anglers in Hawaii (Peter Fithian, personal communication). In recent years, anglers fishing off southern California have become familiar with this species; William L. Craig (personal communication) reports the following verified catches by anglers: off the Coronado Islands, 4 September 1966, 5 feet, 20¾ pounds; 20 miles southwest of North Coronado Island, 31 August 1968, 4¾ pounds; 20 miles south of Pyramid Head, San Clemente Island, 28 August 1969, 45 pounds. The Mediterranean spearfish, *Tetrapturus belone,* though locally and seasonally common off Sicily, has not been reported from anglers' catches (de Sylva, 1973).

The remaining known member of the billfish group, the roundscale spearfish, *Tetrapturus georgei,* from the northeastern Atlantic and western Mediterranean, is apparently quite rare and, to our knowledge, has not been taken by anglers (Robins, 1974a).

The identity of two unidentified specimens of billfish has not been clarified. A juvenile specimen of about 40 mm, on loan to the author from the British Museum (Natural History), was lost in a fire in 1967. The specimen had peculiar markings on the dorsal fin which are reminiscent of those of the white marlin (de Sylva and Ueyanagi, MS). Neither the adult of *T. belone* nor that of *T. georgei* has extensive markings on the dorsal fin; possibly this represents the juvenile of an undescribed species which, though rare, could enter into the sport fishery.

The other unidentified billfish, from the northern Gulf of Mexico, poses special problems. A specimen was caught by Robert Ewing off South Pass (Mississippi River; delta of Louisiana) and, while superficially resembling a white marlin, lacks the distinctive pattern of spots on the dorsal fin, and the dorsal and anal fins are not typically those from a white marlin. I have heard of two other specimens taken from the northeastern Gulf of Mexico. John

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[4] For the purposes of this discussion, I follow Morrow and Harbo (1969) in recognizing a single, worldwide species. Similarly, for the purposes of this review, I concur with our earlier findings (Robins and de Sylva, 1961) that the blue marlin represents a single, circumtropical species.

Rybovich (personal communication), upon examining slides of this fish, indicated that Cuban and Venezuelan commercial fishermen have long been familiar with this form which they called "hatchet marlin" or "axe marlin," in allusion to the truncated dorsal lobe. This form (or species?) could enter the sport fishery in some locations; its taxonomic relationships are presently under study by the author and Dr. C. Richard Robins.

DISTRIBUTION OF SPORT FISHING EFFORT FOR BILLFISH

Billfishes are found throughout the tropical and temperate seas of the world. With the advent of organized commercial fisheries for tuna and billfishes, a mass of data has accumulated on the distribution of billfishes throughout the world's oceans based largely on longline catches (see for example Howard and Ueyanagi, 1965, and references therein; Fox, 1971; Howard and Starck, 1974; Nankai Regional Fisheries Research Laboratory, 1954; 1959; Ueyanagi et al., 1970). Longline catches give some indications of the depth where billfish actually occur because baits are distributed, from many miles of floating line, from the surface to a depth of over 150 m. Billfishes are thus caught using dead baits drifted at various deeper levels, where billfishes apparently spend most of their time. Billfishes may be taken in the upper levels during setting and retrieving of the longline, when the baits are moving through the water (Fox, 1971). In contrast, the sport fishery techniques used for billfishes (which are described subsequently) generally involve a bait which is trolled at the surface, which is not believed to be a normal part of the billfish environment. Thus, for a trolled bait to be seen by a billfish, water transparency must be good and sea conditions such that the bait is visible to the billfish. Considering the small size of the bait and the depth at which billfish normally swim, it is indeed surprising that anglers catch as many fish as they do. We might say that the angler trolling a mullet at the surface will catch only a fraction of the billfish which swim 100 m beneath his boat.

Thus, while from the biological standpoint the distributional charts based on longline catches showing when and where marlin occur are valuable to the prospective longliners, they are of less value to the angler because he is not fishing at the depths where the marlin may be actually commonest and, theoretically, he might troll for months without ever raising a marlin from the depths. Nevertheless, the angler will certainly have a much better statistical chance of success if he fishes when and where billfish are known to occur in commercial catches. In the subsequent section, therefore, reference is made frequently, where appropriate, to geographic areas which are potentially important sport fishing centers for the various species, as well as to those which are already known to be good for billfishing.

Billfish Species and their Distribution

Sailfish are found throughout tropical seas, usually close to large land masses. In comparison to other billfishes, sailfish are found less about islands and tend to come closer to shore into "green water," in contrast to the "blue-water" nature of the other billfishes, possibly merely because of their relative abundance. Sailfish are not especially migratory, although some tagged individuals have traversed great distances. They reach a weight of over 100 kg, and are highly prized by anglers. The juveniles, especially, make handsome mounted specimens. A popular account on sailfishing is presented by Tinsley (1964).

White marlin are found only in the Atlantic. Although they form dense, seasonal aggregations in coastal waters, whites occur far offshore prior to the spawning season. They tend to migrate considerably, and probably consist of two or more populations. White marlin occur frequently in blue water, although one of the largest concentrations available to anglers is in the green, phytoplankton-rich coastal waters of Venezuela. This species, which reaches a weight of about 73 kg, is a spectacular jumper whose acrobatics are perhaps comparable only to those of the related striped marlin.

Blue marlin are confined to the tropics of the world oceans, and apparently do not migrate widely. In the northern hemisphere of the Atlantic and Pacific Oceans they seem to move in a southeast to northwest direction between May and September and conversely from northwest to southeast from November to March. Blues are common near large islands and in the open sea, preferring clear blue water. The International Game Fish Association (IGFA) presently recognizes, for angling purposes, the Atlantic blue marlin and the Pacific blue marlin, though taxonomic differences may not exist. In the Atlantic, the blue marlin reaches nearly 550 kg, while in the Pacific a specimen of 820 kg was landed on hook and line off Honolulu.

Striped marlin are known only from the Pacific and Indian Oceans, although there are records from off Cape Town, South Africa, from the waters of the Agulhas Current, which is geographically in the Atlantic. In the Pacific Ocean the distribution of striped marlin is horseshoeshaped, with a wide latitudinal distribution in the open spaces of the North and South Pacific Oceans. The contiguous distribution connecting these arms occurs in the tropical eastern Pacific, with the open end in the western Pacific. Striped marlin usually do not come as close to land masses as the sailfish or black marlin. Migrations are pronounced, and populations occur in the North and South Pacific Oceans. Like their relative, the white marlin of the Atlantic, striped marlin are spectacular jumpers. Striped marlin grow to about 230 kg.

Black marlin are reported with authenticity only from the Pacific and Indian Oceans. However, Wise and Le Guen (1969), in their analysis of the Japanese longline records, noted that Japanese fishermen report black marlin from the Mid-Atlantic Ridge of the South Atlantic. In a more detailed analysis, Ueyanagi, et al. (1970) show black marlin to be scattered throughout the Atlantic from lat. 30°N to lat. 20°S. In the Pacific and Indian Oceans, they occur in the warmer parts of the oceans near land masses, and are relatively nonmigratory. Because of their large size, they are avidly sought by anglers. The current world record black is 709 kg. A color phase of the black marlin from Tahiti has been long known as the "silver marlin" because of the silvery sheen on the sides. Blue marlin from Pacific Panamá frequently exhibit this silvery pattern, which may reflect local food habits or behavioral patterns.

The broadbill swordfish represents the height of frustration to the angler. Locally it may be abundant but this species frequently refuses to accept an apparently attractive bait. It is perhaps the most widely distributed of the billfishes, yet the occurrence of the swordfish in sport fish catches is extremely rare. Swordfishes occur throughout temperate seas, where they are frequently the subject of intensive commercial fisheries. The larvae are common in tropical seas. Apparently the swordfish undergoes tropical submergence, occurring at greater depths toward the equator and surfacing toward higher latitudes. In temperate waters, anglers spot and catch swordfish close to the surface, and in the tropics the longline catches disclose their presence in deeper strata. Swordfish are usually found far from land masses, though local disfiguration of bottom topography, combined with upwelling, brings food sources closer to them. Swordfish seldom jump, yet they are huge fish, and their scarcity in anglers' catch records and reluctance to take a bait relegate them as a special prize. The present angler record is about 537 kg, although somewhat larger fish are reported to be occasionally captured commercially.

The longbill spearfish is the only one of the four spearfish *(sensu strictu)* to be taken regularly by anglers. Although this species had been taken by anglers in the western Atlantic for years, it was recognized as distinct from other billfishes only relatively recently by the late Al Pflueger who, together with marine scientists, considered it to be similar to the Mediterranean spearfish. Finally, through the efforts of the late John K. Howard, Dr. C. Richard Robins of the University of Miami was able to examine 27 spearfish from the Mediterranean. This study led to the conclusion that the western Atlantic form was a distinct and undescribed species, which was subsequently named *T. pfluegeri* (Robins and de Sylva, 1963). This predominantly offshore species ranges from Georges Bank, Bermuda, the northern Gulf of Mexico, and from Puerto Rico to Brazil. Japanese longline records list spearfish from the Mid-Atlantic Ridge and the Northeast Atlantic to off South Africa (Ueyanagi et al., 1970), but it cannot be stated with certainty as to what species they refer, or even if there is more than one species. In any event, the longbill spearfish is found offshore, being taken only occasionally by anglers. We have data on about 75 fish taken to date, the largest being 40 kg. A summary of the biology and distribution of this species is presented by Robins (1974b).

Important Geographic Regions for Sport Fishing for Billfishes

North America.—The northernmost billfish concentration in North America is the late summer concentration of swordfish at Cape Breton, Nova Scotia, which supports one of the oldest of the billfish sport fisheries (Fig. 1). Swordfish are relatively common south to Montauk, Long Island, New York, where they are taken commercially and for sport. White marlin are not uncommon in late summer from Cape Cod to Montauk. Occasional sailfish and white marlin have been recorded.

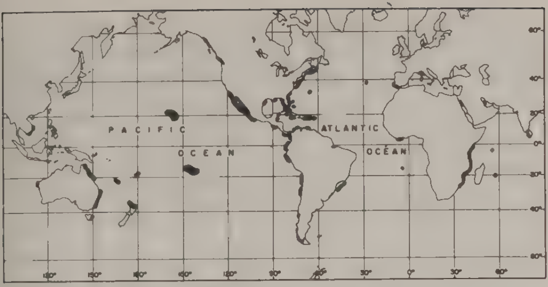

Figure 1.—Principal areas of sport fishing for billfishes.

Middle Atlantic Bight.—This region from Montauk to Hatteras, North Carolina, harbors large concentrations of migrating white marlin during the summer. Large blue marlin are taken frequently off Hatteras, occasionally straying northward, together with sailfish. Swordfish are sufficiently common off Hatteras to support a local, commercial longline fishery, but this species is taken only rarelv by anglers.

Southeast Atlantic Coast.—White marlin, blue marlin, and sailfish are found scattered southward from Hatteras to Cape Canaveral, Florida, but they are not usually available for sport fishing because the Gulf Stream is far offshore and not easily accessible to sportfishing boats. From about Stuart, Florida, south of Cape Canaveral, through the Florida Keys billfishes may be quite common periodically. Sailfish may be abundant at times and blues and whites probably occur throughout the year. Most angler-caught longbill spearfish are reported from this region, and swordfish are not infrequently taken, the latter catches being made usually by anglers inadvertently drifting baits deep from disabled boats.

Gulf of Mexico.—The eastern Gulf of Mexico supports little billfish sport fishing because of the long distance (40-80 nautical miles) to "blue water" where billfishes occur, although organized activity off St. Petersburg, Florida, is beginning to pinpoint the relation between surface currents and billfish distribution. In the northeastern Gulf from around Panama City, Florida, there have been a number of sailfish, whites, and blues taken by a growing sportfishing fleet, and swordfish are occasionally seen at the surface. Nearly all the fishing is carried out in the "Loop Current." Heavy billfishing occurs off the Mississippi Delta for all species of Atlantic billfish. Swordfish have been seen there with increasing frequency, and a few are taken on rod and reel. The Texas coast, especially off Port Aransas, yields good catches of sails and whites, while farther offshore blue marlin probably occur throughout much of the year.

No regular sport fishing for billfish is conducted in the Gulf between the Mexican-Texas border southward until Cozumel where, in the past two years, fleets of American Sportfishermen have traversed the Florida Current to partake of some very exciting fishing for sailfish and white marlin. The results of fishing suggest a catch rate per boat as high as experienced anywhere in the Atlantic.

Eastern Central America.—Mather (1952) reported sailfish, white marlin, and blue marlin widely distributed all along the Central American coast to the Gulf of Mexico at Cozumel, but no extensive fishery is known from this region. There is no reason, however, to believe that sport fishing for billfish should not be reasonably productive along parts of the Central American coast, especially in view of the heavy concentration of blue marlin reported there by Ueyanagi et al. (1970).

Northeastern South America.—Very good angling for sailfish has been reported off Cartagena and Santa Marta, Colombia, but this effort is limited to tournaments, which frequently produce relatively large fish.

Possibly the best angling anywhere for white marlin occurs along the coast of Venezuela off Caraballeda, east of La Guaira. The entire coast here is excellent at least to Puerto Cabello, where blues and sails occur, and where whites are common. Spearfish are occasionally landed along this coast. The waters from Puerto Cabello westward to Lake Maracaibo have not, to my knowledge, been explored by anglers.

East of Venezuela, the heavy influx of fresh water from the Orinoco and Amazon Rivers, with the associated high turbidity, does not favor billfish sport fishing, although commercial fishermen do catch billfishes offshore of and beneath the relatively shallow freshwater effluent. From Fortaleza, Brazil, to São Paulo, billfishing activity is limited, probably because blue water is too far offshore and outside the range of most Sportfishermen. Longliners take good catches of blue and white marlin offshore of the entire coast. Whites, sails, and blues are taken by those intrepid anglers capable of the offshore run of 150 to 200 nautical miles to the warm, blue waters. Farther south, swordfish are scattered off southern Brazil and even Uruguay and Argentina, but sport fishing for them off eastern South

America apparently is extremely limited.

Bermuda.—Turning northward again to the western tropical North Atlantic, Bermuda has been a historical focal point for big game fishing, with billfish species being well represented from the waters of Bermuda and the adjacent Sargasso Sea. Although large whites and blues are caught with regularity, these waters do not yield billfish in large numbers. Mowbray (1956) showed that billfish could be taken off Bermuda by deep drift-fishing, which may well be a valuable technique in the oceanic tropics in locating billfish which penetrate the thermocline in search of food.

Bahamas.—The 3,000 islands comprising the Bahamas have always lured tourists, yet the waters surrounding only a few of them have been fished for billfishes. This is undoubtedly due to the tremendous geographical expanse covered by these islands and the relative lack of port facilities for big-game fishing. Notable exceptions are Bimini, Cat Cay, Chub Cay, and Walker Cay, which are less than 200 island-hopping nautical miles from the mainland United States. These islands have historically produced many world-record game fish, including several-score records for billfishes on various kinds of tackle. Blue marlin apparently occur throughout the year, with whites and sails being caught especially in the spring. A few spearfish are taken annually, and swordfish are seen though seldom hooked. Charts based on Japanese longline catches show heavy concentrations of blue marlin several hundred nautical miles east of Eleuthera and Abaco Islands in late spring and summer, but the distances from even the nearest major port (i.e., Nassau) are presently too far for most anglers.

Caribbean.—Cuba, the largest island of the Caribbean, and a historical producer of the blue marlin and white marlin, is presently off limits for most anglers. An annual Ernest Hemingway Tournament still yields good catches of white marlin according to the Cuban journal *Mar y Pesca,* while commercial fishermen fish deep, using drift lines, to catch the kind of swordfish and blue marlin revered in Hemingway's "The Old Man and the Sea." From commercial catch records spearfish are apparently found scattered along the coast and in offshore waters; however, they have not been reported by anglers.

Jamaica is a superb fishing area for small blues of about 70 kg, these fish being especially numerous during the fall sport fishery on the northeastern coast of Jamaica. Large blues are taken by commercial drift-fishermen along the northwest, the south, and, especially, the northeast coasts of Jamaica. Swordfish are occasionally taken by drift fishermen fishing deep off Jamaica, as well as throughout most Caribbean waters, but these strata are not fished by sport fishermen. A few blue marlin are taken by anglers in the nearby Cayman Islands, but fishing effort is too sporadic to suggest definitive fishing areas or seasons.

The Dominican Republic has yielded good catches of white marlin, especially about Boca de Yuma on the southeastern coast. Sailfish and, occasionally, blue marlin are taken there. The rest of Hispaniola, though potentially exciting for billfish, has not been explored.

The north coast of Puerto Rico has long been an excellent spot for blue marlin, including a one-time world's record of nearly 344 kg. In past years good catches of blues, plus a few whites and sails, and occasional spearfish and swordfish have been made. Presently, the sport catch seems to be attenuating, possibly in conjunction with the increasing levels of pollution in Puerto Rican waters.

Over the years the habitat east of Puerto Rico, especially the Virgin Islands, has consistently produced good catches of relatively large blue marlin, together with scattered catches of whites and sails. Reputedly, blue marlin of over 500 kg have been hooked and lost east of St. Thomas. There is no reason to doubt these claims, for shark-mutilated carcasses of large marlin of at least this size have been seen or brought in by fishermen fishing in waters off the large islands of Puerto Rico and Cuba. However, in view of the reports of black marlin from mid-Atlantic waters (Ueyanagi et al., 1970), the identity of these large fish is speculative.

The waters of the Leeward and Windward Islands, from Anguilla to Grenada and Barbados, yield an occasional billfish to commercial drift-fishermen. Angling effort is presently almost nonexistent in this region, possibly due to lack of harbor facilities or appropriate sportfishing boats. In addition, billfishes, as reflected in commercial catches, do not seem especially abundant here in comparison with other tropical western Atlantic grounds.

West Coast of South America.—The angling world's record broadbill swordfish of 537 kg was taken at Iquique in northern Chile. Although local sportfishing activity is centered in Iquique, the facilities are limited and fishing effort not extensive. Swordfish are taken commercially at least as far south as Valparaiso by harpoon (Manning, 1957);

sportfishing facilities are not well developed there. Striped marlin are also very common in northern Chile and are taken by sport anglers fishing off Iquique. Black marlin and sailfish may occur when tongues of warm water penetrate from the north.

Swordfish, striped marlin, and black marlin historically are relatively common in Peru. Large blacks have been taken by commercial and sport fishermen working out of Cabo Blanco, but in recent years angling has attenuated in part due to an apparent lack of interest by foreign anglers and allegedly in part due to the reported offshore displacement of the Peru Current which harbors these large billfish and the complex food web upon which the large billfishes depend.

Large black and striped marlin occur abundantly all along the Ecuadorian coast, outside of the Gulf of Guayaquil, between Manta and Esmeraldas, including Isla de la Plata. Recently, excellent angling for striped marlin has been reported off La Puntilla, west of Guayaquil. Blue marlin and sailfish are common when warm currents predominate, while black and striped marlin favor cooler waters, as do the occasional swordfish hooked offshore.

Sport fishing for billfish has never been adequately explored along Colombia's west coast. Very large sailfish and black marlin are seen or hooked offshore, especially around Gorgona and Gorgonilla Islands, southwest of Buenaventura. Blue marlin are also reported here and, undoubtedly, striped marlin occur seasonally during cooler periods.

Western Central America.—Billfishing is excellent all along Panamá's Pacific coast. Piñas Bay and the Pearl Islands are historically the headquarters for excellent billfishing in Panamá waters where black, blue, and occasionally striped marlin abound. Sailfish are especially large and plentiful all along Pacific Panamá. Anglers devoted to fishing with light tackle and artificial flies speak reverently of sailfishing in these waters.

Some sport fishing for Pacific sailfish occurs near Puntarenas, Costa Rica. Heavy surf and swells reduce the feasibility of launching small angling boats safely.

Off Nicaragua, black marlin and sailfish are reported by commercial fishermen, but the surf and swell are similar to that of the Costa Rican coast. In addition to the lack of adequate sportfishing ports and facilities, the sea conditions discourage sport fishing for billfishes.

The Pacific coast of Honduras northward to Mexico is characterized by a shortage of large waterfront cities and suitable ports. El Salvador commercial fishermen report sailfish from this coast. However, this entire region, though rich in fish and good fishing waters, suffers from a lack of protected harbors and fishing docks, facilities which are expensive and difficult to build and maintain.

Western North America.—Sailfish, striped marlin, blue marlin, and, to a lesser extent, black marlin occur all along Mexico's Pacific coast. The best-known ports are Acapulco and Mazatlán, although in recent years Cabo San Lucas (in Baja California) and Manzanillo have reported excellent catches of billfishes. Sailfish and striped marlin are common in the lower parts of the Gulf of California as far as Isla Tiburón. Commercial longliners fishing just offshore of these areas have captured prodigious numbers of striped marlin and sailfish; their efforts are evidently affecting the size of the individual sport fisherman's catch (Gottschalk, 1972). Swordfish are frequently seen off Baja California and are occasionally hooked by anglers.

Striped marlin and swordfish have been fished by anglers since the turn of the century. The Tuna Club of Avalon has consistently made good catches along the continental shelf of southern California (Howard and Ueyanagi, 1965). Recent shifts in the currents off southern California apparently have affected the distribution of swordfish and striped marlin and their availability to the angler.

Europe.—Sport fishing for billfishes in European waters is limited, and concentrated about the Straits of Gibraltar and the western Mediterranean Sea. Spanish and Portuguese anglers fish for broadbill swordfish (Cordeira, 1958) and catch an occasional white marlin; these species are also caught around the Azores. According to various reports from the journal *Mondo Sommerso,* sport fishing for white marlin is frequently successful in the Ligurian Sea, off northwestern Italy, while blue marlin are also occasionally taken (*Mondo Sommerso,* 1968). Most angling is sporadic, however, because of the relative scarcity of billfishes other than swordfish. Little angling information for swordfish is available for most of the Mediterranean, and it is unknown if sport fishing is presently carried out in the Black Sea or the Sea of Azov. Swordfish are taken commercially from the Black Sea and the Sea of Azov (La Monte and Marcy, 1941). La Monte and Marcy reported that, at the time of their writing, there was no sport fishing for swordfish in the Sea of Marmora (Turkey), though Lebedeff (1936) reported excellent angling there for swordfish. Mediterranean spearfish are taken commercially in the central Mediterranean, including the Ligurian, Tyrrhenian, Ionian, and Adriatic Seas, but there are no reports of catches by anglers (de Sylva, 1973).

Africa.—Sailfish occur along the African coast from at least Dakar to the Gulf of Guinea. This species supports a sizeable commercial fishery off the Gulf of Guinea (Ovchinnikov, 1966). The world-record Atlantic sailfish of 64 kg came from the Ivory Coast, a location where sailfish are reported to occur frequently. Undoubtedly, sailfish are potentially plentiful to the angler along the coast from Dakar into the Gulf of Guinea, although angling facilities including suitable trolling boats are probably scarce. Blue marlin are reported from off Dakar, Guinea, Sierra Leone, and into the Gulf of Guinea, and have been caught by anglers at Ascension and St. Helena Islands. Black marlin are reported in the Japanese longline catches to occur along the Mid-Atlantic Ridge (Ueyanagi et al., 1970); however, no authenticated catch has been made by a commercial or sport fisherman. Swordfish are frequently taken from deep waters along the West African coast.

East and South Africa.—Excellent marlin and sailfish angling (Williams, 1970) occurs from Malindi (Kenya) southwards to Durban (Natal). Black marlin, striped marlin, blue marlin, and sailfish are taken seasonally along the coast. White marlin, shortbill spearfish, and longbill spearfish have been reported from waters off South Africa, in an area of mixing between Atlantic and Indian Ocean currents (Penrith and Wapenaar, 1962; Ueyanagi et al., 1970), but their occurrence is rare. Kenya and Mozambique are also extremely important areas for sportfishing for black marlin and sailfish (Howard and Ueyanagi, 1965), while swordfish are taken on longlines in this region. Large black marlin are taken commercially off northern Madagascar, and sailfish are reported to be taken commercially from waters around the Comoro Islands. There is good angling for black marlin off Mauritius, while commercial charts reveal heavy concentrations of black marlin in the Indian Ocean east of Madagascar along the parallels of lat. 0-10° (Howard and Ueyanagi, 1965; Howard and Starck, 1974).

To the north, sailfish have been caught by anglers in the Gulf of Aqaba, Red Sea, and the Gulf of Aden. This species may develop as a sportfishing resource as facilities become available. However, no data are available on seasonal or relative abundance of sailfish in this area. Large sailfish are taken occasionally by anglers in the Persian Gulf.

India and Ceylon.—Black, blue, and striped marlin and sailfish are known to occur in Indian coastal waters, but there has been little angling expended in the area. Ceylon has yielded some large black marlin, while shortbill spearfish and swordfish are commercially taken in deeper waters. Deraniyagala (1937: 348) reported that the swordfish "is not uncommon in deep water to the south and east of Ceylon."

In the central Indian Ocean east to Sumatra and western Australia, commercial fishing records reveal good catches of black, blue, and striped marlin. Occasional swordfish and shortbill spearfish are also taken. However, sportfishing facilities are limited in these waters and probably will not increase greatly in the future. Howard and Starck (1974) present seasonal distribution charts of longline catches of billfishes from these waters.

The South China Sea and Malaysia.—From longline catch records marlin and sailfish are reported to occur throughout Indonesia, the South China Sea, and the Timor and Arafura Seas. Little sport fishing occurs in these waters, largely because of the lack of port facilities and angling equipment. Commercial concentrations of black marlin occur throughout this region. Patrol boats working the Indochina coast have, in their so-called leisure time, seen and hooked black marlin not far from South Viet-Nam, though the fish are small and scattered. Although sailfish are common in the fall season close to the coast off Nhatrang, South Viet-Nam, the shallow continental shelf along Indochina appears unfavorable ecologically for the larger members of the billfish family.

Japan and the East China Sea.—Huge concentrations of striped marlin and sailfish occur off southern Japan. But these concentrations are sufficiently far offshore to be past the ordinary range of potential sportfishing vessels. Presently, however, there is little demand for offshore sportfishing facilities in the area despite the occurrence of many potential game fish species in Japanese waters. Black marlin occur throughout this region, but are not fished for by anglers. Billfishes are also common east of Taiwan, where they are taken commercially, but no sport fishery exists for them.

Indonesia, Philippine Sea, and the Philippines.—Billfishes are relatively uncommon in this region, possibly because the thermocline, which is reported to concentrate food, is deep and below angling depths. Scattered catches of black marlin and sailfish are reported by commercial fishermen, but it would appear that the development of billfish angling would be limited in this area because of the probable scarcity of billfish. According to longline records, black marlin and sailfish are found in concentrations in the various seas throughout Indonesia. Striped marlin are common south of Java.

Micronesia and Melanesia, including New Guinea.—Black marlin occur in commercial quantities close to New Guinea, but these fish are not sought by anglers. High concentrations of black marlin and sailfish occur in the East Java Sea, and the area between New Guinea and Australia, as well as in the Caroline and Solomon Islands and the Banda and Timor Seas. While these areas are not presently fished by anglers, they may offer good sportfishing potential.

Goadby (1970:71) wrote that "big fish are all through these islands," referring to the New Hebrides, the Solomons, Tonga, the Gilbert and Ellice Islands, and Western Samoa. Blue marlin are common about New Hebrides, while New Caledonia has blacks and blues. In Samoa there are two commercial tuna canneries at Pago Pago; the Japanese report high catches of tuna, together with billfishes, from these waters. Blues, blacks, and sails are common offshore. Good potential sportfishing areas for blues exist throughout the Marshall and Marianas Islands, while Papua and New Guinea yield small black marlin and sailfish.

Near Fiji, big black marlin estimated at nearly 700 kg have been taken by commercial fishermen on hand- and longlines working off Suva and Koro Levu. These large blacks are especially prevalent during October. Sailfish up to nearly 80 kg and big blue marlin are not uncommon.

Australia.—When dealing with sport fishing in the Pacific, it is difficult to refer to anything but Peter Goadby's recent book, "Big Fish and Blue Water" (Goadby, 1970). In addition to tracing the history of big-game fishing off this productive coastline, Goadby deals with the actual and potential fishing for various billfishes from the major Pacific ports. The serious or potential angler is referred, therefore, to his book. A few of the high points involve the superb billfishing in Australia. Off Queensland, in the northeast, huge black marlin in the 450- to 550-kg class have been taken with increasing frequency. Fishing off Cairns and all along the Great Barrier Reef yields blacks, as do the areas of South Queensland and New South Wales. Sailfish are commonly taken off the Great Barrier Reef off North Queensland, while New South Wales is good for striped marlin. There are no authenticated records of any species of marlin taken from waters off Tasmania, although swordfish are taken from these cool waters. Off Western Australia, black marlin and sailfish are occasionally taken, while longline records show heavy concentrations of black marlin off Northwestern Australia.

Among the many firsts for Australia, listed by Goadby, is the first record of a shortbill spearfish (20+ kg) taken on rod and reel, off Port Stephens north of Sydney.

New Zealand.—Since Zane Grey's early big-game fishing operations, northern New Zealand waters have been a continued attraction for fishing for swordfish and striped marlin. The Bay of Islands yields many large striped marlin as well as large black marlin, and in recent years more blues have been caught, possibly because anglers have only recently been aware of their presence in the South Pacific.

French Polynesia and the Line Islands.—Heavy concentrations of blue marlin have been reported by Japanese longliners to occur throughout the Society Islands and the Tuamotu archipelago. Reports of giant blue marlin taken by native fishermen continue to emanate from Tahiti, but blue marlin sport fishing based in Tahiti has not yet been widely developed. A blue marlin estimated at over 1,140 kg was caught off Moorea by a commercial fisherman, and blues over 330 kg are common. The black marlin frequently taken in waters off Tahiti exhibit a pale color phase, which Zane Grey referred to as the "silver marlin." Large sailfish are frequently taken off Tahiti, one of which weighed nearly 90 kg.

The Hawaiian Islands.—Last, but not at all least, are the Hawaiian Islands, whose sport fishing catches are world famous. Of course, the Kona coast continues to yield good catches of blue marlin and striped marlin. Blue marlin are also taken close to Oahu over the nearby banks. A huge blue marlin (an 820-kg fish) was taken off Oahu; however, it was ineligible for IGFA recognition because several anglers fought the fish. During periods of cooler water, striped marlin are common. Goadby (1970) reported that Kauai, the western side of Molokai, and the south coast of Maui are all excellent grounds for billfishing. Sailfish are occasionally caught by anglers, while spearfish and swordfish are taken by commercial longliners. For further detailed information on Hawaiian billfishing, Goadby's book is *the* source.

Royce (1957) and Strasburg (1970) have discussed the distribution and size composition of billfishes taken by longline vessels in Hawaiian waters and other regions of the Central Pacific.

MECHANICS OF THE SPORT FISHERY

Sport fishing for billfish, as well as tuna, is unique in its requirements for specialized and expensive gear. With few exceptions, the success of an angler in finding, hooking, and landing a billfish is directly proportional to the finding, fishing, and maneuvering expertise of the captain and mates, the overall character of the sportfishing vessel and the quality and resolving power of its navigational and depth-sounding equipment, the reliability of the rods and reels, and the special know-how required of the captain or mate to make a dead bait troll so that it ''swims'' like a live one. The cost to a banker from Chicago or a secretary from New Orleans will still cost $100 to $1,000 a day, depending on where the billfish are sought and the captain's reputation as a skilled ''fish-getter.'' Of course, the person who chooses to own a billfishing vessel and maintain a captain, mate, and the vessel's annual expenses will have to underwrite costs well over the $100,000 mark. Exact data on expenses incurred by billfish and tuna anglers are not presently available. We are currently collecting and analyzing these kinds of data as part of a survey of the billfish and tuna sport fishery of the western hemisphere for the National Marine Fisheries Service. In the questionnaires we mailed to thousands of big-game anglers, we requested confidential information on the various expenses incurred in fishing for billfish and tuna. Most anglers happily complied, but some who did not indicated that if they ever stopped to calculate how much they spent they would never go fishing again. Billfishing might thus be classed as the sport of kings merely because of the cost. But the rewards are high, the excitement is tense, the memories are forever, and an increasing number of persons in the middle-income bracket are finding ways to save their money for that dream trip to troll off Hawaii or Bimini for that big blue.

The most complete description of a Sportfisherman—this being an inboard power boat designed specially for offshore fishing—is given by Rybovich (1965), and for detailed information the reader is referred to this article. Sportfishermen are usually 36 to 42 feet long, and have numerous specific features which are unique (Fig. 2). Among these are the tuna tower, especially helpful in locating billfish or tuna, baitfish, or birds feeding on the baitfish which frequently indicate billfish. Better visibility from the tower permits the captain to ''bait'' the fish, such as is done for swordfish and tuna, by circling them with a trolled bait. The flying bridge, from which the captain can maneuver the boat while looking ahead or watching the angler and the fish he may be fighting, has its own set of controls. Outriggers have long been used to skip trolled baits at the surface on the theoretical premise that billfish will think that they are seeing their favorite food—flyingfish—and will be irresistibly drawn to them. In reality, billfish hardly ever eat flyingfish, but it gives the angler a thrill when that rare stray marlin comes up from the depths to see what damn fool is dragging an estuarine mullet 50 nautical miles offshore. The line from the rod and reel in the cockpit is fastened to a line from the outrigger tip by a spring-release clip so that when a fish hits the bait, it drops back. According to the late Tommy Gifford, inventor of the drop-back technique, this gives

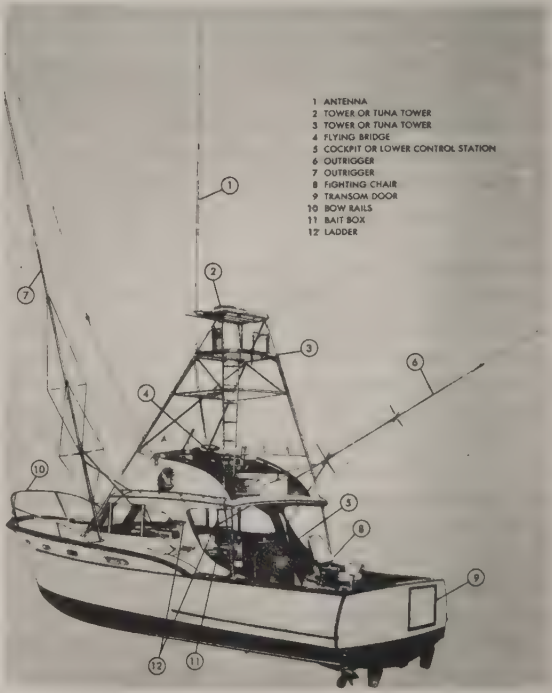

Figure 2.—Schematic diagram of a Sportfisherman (from Rybovich, 1965).

the fish the impression that it has killed its prey. In any event, the billfish has a second chance to swallow the trolled bait during the brief instant when the bait is not moving through the water. And because outriggers are rather expensive, the drop-back technique, though not necessarily effective in catching fish is great for outrigger manufacturers.

A gaff (a large, barbless hook attached to a handle) or a flying gaff (a hook which detaches from the handle, for large fish) may be used to bring small fish on board. For larger fish, a gin pole is used. The gin pole is a vertical beam, approximately 10 × 10 cm, with a block and tackle at its upper end, used to lift large fish into the boat. A tail rope (a noose which can be slipped about the caudal peduncle of a large fish) is suspended from the gin pole, and the catch hoisted on board. In recent years, the tuna door on the transom has become popular. The door is merely opened and the fish dragged on board at waterline level. This method is also much safer to the onlookers who may lose limbs from the thrashing spear of the aptly named billfish.

The teaser is a hookless wooden, plastic, or metallic object, usually of bright color or reflective substance, which is towed from a short, heavy cord from behind the boat. Teasers vary from highly machined and expensive darting and flashing objects to rubber squids and fish, or to beer-can openers, sardine cans, bed sheets, and underwear. In fact, probably teasers, whatever their origin, are equally as important in attracting billfish as the type of baits presented.

A single fighting chair with the built-in footrest is usually amidships in the cockpit, but there may be two or three. This sturdy, specialized chair is on a swivel with a gimballed rod holder at the base of the seat for use when fighting the fish, as well as one or two rod holders on the arm rest.

The ideal Sportfisherman is basically designed for range, speed, and maneuverability, and has the ability to tolerate reasonably bad weather, a period when billfish frequently are more active. These boats historically were gasoline-powered, but high-performance diesel engines (although at a higher price) can add endurance and range to a Sportfisherman. Boats capable of 20 to 30 knots are not uncommon today. Such vessels are not meant for the angler's comfort for more than a day, although the crew may live aboard. The most important facilities to the angler are a good livebait well and a good ice box for fresh bait and ice.

Speed and maneuverability, so important to billfishing, are a function of hull design. Specific types of hull designs vary somewhat with each manufacturer of Sportfishermen (e.g., Hatteras, Bertram, Huckins). Recently, however, there has been a trend to a specifically designed small Sportfisherman having an open-cockpit, in the size range of 7 to 10 m, usually with a deep V-hull (Robert D. Stearns, personal communication).

Rybovich (1965) summarized the principles involved in considering speed and maneuverability, as well as theories behind the outrigger, flying bridge, gin pole, transom door, tuna tower, fishing tackle, and electronic equipment, all peculiarities of sport fishing for billfishes and tuna. Electronic equipment is extremely important in locating fish. Wealthier anglers may employ their own spotter planes to help them locate fish, in much the same way menhaden commercial fleets have their planes to indicate when and where to set their purse seines. In lieu of spotter planes, the captain of a Sportfisherman must attempt to locate or return to a fishing spot which he knows to be productive. For this he needs an RDF or, better, radar and loran; possibly the more affluent anglers will be using satellite navigators at $45,000, a small price to pay when one has already spent $100,000. A good depth indicator, preferably a recorder on which one can detect bottom contours for future reference, will help the angler to find his favorite fishing ground, as well as his safe return home.

The tackle itself is extremely specialized. Because of the large fish involved and the speed of the trolling boat, the force exerted on all gear is quite large. Fiberglas rods are custom-built for billfishing, while reels must be carefully constructed and maintained. Line which has a breaking strength of 12, 20, 30, 50, 80, and 130 pounds is used for various species, depending on the circumstances, each of which relegates fish caught on that test line to a particular category within the IGFA classification. Wire leaders are specially and carefully prepared, as are the swivels and snaps for the terminal tackle. Hooks, which are expensive, are carefully chosen for the type of fishing and the species sought.

Baits are frequently among the most controversial item for billfishes. One can travel far and wide and never get the same answer from fishing captains. Among the most widely used billfish baits in the United States are the mullets (*Mugil*), possibly because of their availability. Bonefish (*Albula* spp.) are popular, as are balao, or ballyhoo *(Hemiramphus* and relatives), mackerel *(Scomberomorus),* barracudas *(Sphyraena),* dolphin *(Coryphaena),* rainbow runner *(Elagatis bipinnulatus),* jacks *(Caranx* spp.), tunas and bonitos *(Thunnus, Katsuwonus, Euthynnus, Sarda),* squids of several genera, flyingfish (Exocoetidae), and artificial and rigged eels (*Anguilla*) and eel skins. Artificial lures trolled as baits are locally popular, including rubber squids, sauries, mackerel, bonitos, halfbeaks, and eels. One of the largest restrictions to the development of sport fishing for billfish in new areas is the guarantee that an adequate, continual supply of fresh bait will be available, and at a reasonable price. Anglers and skippers have been reluctant to use preserved or artificial bait, in spite of the high billfish catches obtained by commercial longliners using salted or dried bait (squids, sauries, mackerel, which are not even trolled), or the probable inability of billfishes to distinguish between trolled baits which are fresh or preserved in Formalin.

It is important to note that anglers using expertise, boats, tackle, bait, and navigational equipment which are minimal in quality probably will catch fish, but that the quality of these facilities and expertise is directly proportional to angling success. A rule which might be applicable to billfishing is that the more you spend the more you catch.

Finally, it should be stressed that billfish angling is very inefficient. A few captains troll a single bait, while most troll four (two outriggers with skipped bait and two baits trolled slightly subsurface from "flat-lines") or six (four outriggers and two flat-lines). These baits are being trolled at or within a meter of the surface; hence, the billfish, which normally are subsurface feeders, may not see these relatively tiny baits, especially if the sea surface is rough, or if visibility is poor due to clouds or turbid water from various causes, and under such conditions the chance of catching a billfish therefore becomes less. This method is in contrast to the relatively successful commercial longline which fishes from near the surface to over 150 m beneath the surface and which entails up to 60-75 km of longline involving up to 2,000 hooks. That the angler may catch more billfish when none appears at the surface has been shown in numerous angling tournaments by the intrepid and nonconformist anglers who dared to drift a bait at 50-100 m. Those who did occasionally won the tournament (and within the confines of IGFA rules), yet were suspect and outcast because of their devious ways. It may be concluded that while billfish captains and anglers are usually quite successful, most seldom attempt to try new ideas which will deviate from past tried and true methods.

SIZE OF CATCH

It is interesting to speculate on who catches the largest individual billfish, using what type of lure, under what conditions, and where. No data are available to compare the efficiency of sport and commercial fishermen using trolled baits versus longline *per hook*. Clearly, longlines are more efficient because they fish at the depth where billfish feed, and because there are more hooks fishing at that depth. Yet we do not know if a cleverly rigged, surface-trolled mullet, fished at the surface will catch more fish per unit effort of hook. Similarly, data are unavailable to determine whether a longline or angler-trolled bait catches larger fish. There is no evidence either way that the very large billfish—those above 500 kg—are more or less able to break the hook or gangion (drop-line) on a multiple-hook longline rig, versus whether they are easier to fight and land on a single hook. This controversial question is open to serious discussion, for it is equally meaningful to the commercial or sport fisherman who wants large fish. If only large fish are available to the longliners yet they cannot be landed because they snap the hook or gangion, then there is no point in fishing for them, and therefore areas reportedly harboring large fish could be avoided. Conversely, the angler is usually not interested in large numbers of small marlin, and would tend to seek those huge marlins which can be hooked, fought, and landed which take advantage of the "give" in monofilament or Dacron line, the bend of the rod, and the captain's ability to determine the fight which the fish will be able to offer.

Data are needed on all billfishes caught by the angler. Possibly, only small fish are released, so that the scientist obtains a biased estimate of the size of the angler catch, whereas fishermen who fish commercially for billfish retain all fish. Examination of taxidermists' records, however, do not suggest differential release of very small or very large fish, although very small billfish (less than 5 kg) are uncommon in anglers' catches because of the large baits trolled.

Earle (1940) and de Sylva and Davis (1963) presented data on sizes of white marlin from the Middle Atlantic Bight, from Long Island, New York, to Hatteras, North Carolina, while Erdman (1962, 1968) and de Sylva (1963) reported on sizes of blue marlin taken at Puerto Rico and Jamaica, respectively. Williams (1970) presented extensive length and weight data on sailfish taken from off Kenya, East Africa. Size distribution of sailfish, as reflected in taxidermists' records, from the southeastern United States, were reported by de Sylva (1957). To this writer's knowledge, these represent the sum total of published size data on the sport fishery for billfishes. A detailed analysis of the size-frequency distribution of billfish in the sport catch in the western hemisphere is presently being carried out by the writer, but, except for a few specific areas (Maryland, North Carolina, south Florida, Jamaica, Puerto Rico, the northern Gulf of Mexico), few good data are available. Therefore, a request is made herein to any anglers or angling clubs in the western hemisphere who have records of the size of billfish they have caught, or catch per effort data, to submit them for analysis.

TIME OF BILLFISH ANGLING

Swordfish feed more frequently at night, as indicated by longline catches, although they are taken by anglers during the day. Possibly the difficulty which anglers experience in getting a swordfish to take a bait is associated with its poor daytime visibility, or because it also feeds by smell.

The istiophorid fishes feed largely by sight. Longline catches, and the condition of the stomach contents of billfishes, indicate that they feed at dawn and dusk, when they probably rise closer to the surface, descending to deeper levels during daylight hours, possibly just above the thermocline.

The angling effort for istiophorids is conducted almost exclusively from 8, 9, or 10 a.m. until 4, 5, or, at the latest, 6 p.m. Hence, most angling for billfish is done not only when they are not actively feeding, but also when they are swimming at subsurface depths. That small fraction of the billfish population which does rise to the bait trolled during daylight hours may be hitting the bait out of curiosity, as evidenced by the occasionally very full stomachs of billfish taken by anglers. In short, billfish anglers usually fish at the wrong time. Sport fishing for billfish is often merely a part of the overall relaxation pattern for an angler, and he usually fishes during the day and returns relatively early, usually well before dusk, for relaxation back at port. Hence, even though the captain may feel that he *should* fish later, the angler may suggest that fishing cease earlier. Of course the frequently long runs to and from the fishing grounds and the sometimes tortuous navigation path back home may not permit the captain to fish late. Those captains who make runs to the fishing grounds and overnight on them, so that they *can* fish earlier or later than usual, frequently make good catches.

Few data are available from anglers' or captains' logbooks on the best time of fishing. However, data from the Bahamas and Jamaica suggest that from 6 to 9 a.m. and from 3 to 6 p.m. are the best for getting strikes (de Sylva, 1974). It is not known if billfish will take a trolled bait between 6 p.m. and 6 a.m. because little, if any, angling is conducted during this period.

SPECIAL PROBLEMS OF THE BILLFISH SPORT FISHERY

Sport fishing activities for billfish in the past have not been well documented. There is a pressing need for qualitative and, especially, quantitative information if this valuable fishery is to be managed, and if the potential sociological conflict between sport and commercial fishermen is to be resolved. Now that we are faced with growing environmental problems, such as the deleterious effects of polluted water on sailfish or the high concentrations of heavy metals in swordfish, we must pay more attention to the dynamics of the marine environment. These much-needed data can only be obtained through the cooperation of the angler, commercial fisherman, boat captain, the sport and commercial fishing industry, and the scientist. Let us consider, therefore, the components of the sport fishery which are so peculiar to billfish.

The Fishing Grounds

Sportfishing grounds for billfish are greatly in need of having their ecological characteristics defined. There is a serious lack of information on the physical and chemical characteristics of the angling grounds, including the distribution of temperature, salinity, oxygen, and turbidity, and their interaction with plankton, micronekton, and billfish. How these factors interrelate with one another may affect the feeding, vertical and horizontal movements, and general behavior of both the billfishes and their food. Most of all, these data are needed so that the scientist can reduce them into terms readily understandable to the angler. The term "fisheries oceanography" has been used to describe the application of oceanographic principles so that the commercial fishing boat skipper can locate commercial concentrations of fish (Hela and Laevastu, 1971). However, this concept has seldom been used either by captains of Sportfishermen or by scientists to locate good billfishing grounds for the angler. This seems to me one of the mutual goals of scientists and anglers.

Fishing grounds can sometimes be improved through artificial habitats. Artificial reefs are bottom structures used to attract bottom or midwater game fishes, yet the *tsuke* rafts of the Japanese —bales of straw or other floating or anchored structures—could be used to attract small fishes upon which billfish feed.

Possibly the greatest threat to our billfish sport fisheries resources in not overfishing but manmade environmental changes. Billfish sport and commercial fishery interests must join together in reducing present pollution levels and preventing new sources of marine pollution. Pesticides, PCBs, heavy metals, sewage wastes, and various hydrocarbons (mostly oils and tars) not only are potentially dangerous to various stages of the life cycle of billfish and the organisms on which they feed, but these compounds are concentrated sublethally in various parts of the billfish, making them potentially dangerous to human consumers (Wilson and Mathews, 1970). Pollution damages not only the living resources but also the fishing grounds by removing oxygen, adding toxins which may cause fish to change their behavioral, migratory, reproductive, or feeding habits, and increasing turbidity so that billfish cannot see baits trolled from boats. In Palm Beach County, Florida, the latter phenomenon apparently has forced billfish anglers to go much farther away to find sailfish, with a resulting increase in fuel costs and a lessened amount of time which can be devoted to actual angling. Dredging, filling, and the disposal of untreated sewage all combine to turn Palm Beach's once-blue sailfish waters to the shade of weak coffee. The basic problem is that such environmental degradation is not being documented, which is sorely needed if appropriate restorations are to be made.

A special occupational hazard of billfish and tuna anglers is the shark problem. A single shark bite will disqualify a potential record game fish from qualifying under IGFA rules and, hence, the angler needs to boat his fish safely and rapidly. Sharks occur wherever billfish swim, but their tendency to attack billfish is not well understood. In very clear tropical waters they tend to attack less, while in murky or polluted waters they become fierce, frequently going into the so-called "feeding frenzy." A knowledge of why sharks attack a billfish might aid the angler in avoiding areas of potential shark attack and, hopefully, lead to some effective shark repellent.

Habitat improvement, pollution reduction, and shark deterrents are all important goals to billfish anglers which could be cooperatively studied by anglers, boat captains, tackle and boat maufacturers, local, state, and federal governments, and scientists. Such cooperation, at all levels, should be one of the goals of this Symposium.

The Boat Captain

Like all ship captains, the captain of a Sportfisherman is stubborn, brilliant, cantankerous, dedicated, independent, and unshakable in his habits. If he is an unusually competent fish-getter, his beliefs are even more entrenched, while if he does *not* produce for the angler consistently, he can blame his poor catches on wrong tides, poor weather, lack of baitfish on the grounds, bad bait, too low water temperatures, pollution, nuclear fallout, or Japanese longliners.

With all his other problems of keeping his ship operating perfectly, catering to wealthy and often difficult anglers, catching fish, and getting back to port, the skipper actually has little time to learn new techniques or to search for new areas even if he *wants* to. Scientists stress the need for accurate log books to be placed aboard Sportfishermen so that strikes, water temperatures, bird flocks, and sea and wind conditions can be recorded. Many skippers actively tag billfish in cooperation with tagging programs of Woods Hole Oceanographic Institution or the Tiburon Fisheries Laboratory, though the maintenance of carefully maintained logbooks is frequently beyond the physical capability of the captain.

Most billfish captains are intelligent, friendly, and inquisitive about marine science, and especially about the fish upon which they depend for

ieir living. Many can and will help scientists in
ie acquisition of reasonable quantities of data
hich will yield information for science as well as
› help him make a better living. Sport fishing cap-
iins have cooperated with scientists by tagging
sh, collecting specimens, stomach contents, or
onads, collecting water samples and plankton,
iking water temperatures, and releasing drift
ards for current studies, as well as by maintaining
ogbooks of when and where they caught fish. But
ie boat captain really has little scientific informa-
on on the habits or ecology of billfish, and he can
btain this only through conversation, in nonscien-
fic language, or by reading nontechnical articles.
: is the duty of the scientist to supply this infor-
iation if he is to receive continued cooperation.
xcellent examples are the newsletter which
rank Mather sends to all his billfish taggers and
ie circular of the Southwest Fishery Center
NMFS) sent to anglers in the Hawaiian Interna-
onal Billfish Tournaments. A similar but different
ervice is performed by the International Game
ish Research Conference, sponsored by the In-
ernational Oceanographic Foundation in Miami.
t these annual meetings, anglers, guides, boat
aptains, news writers, and scientists gather to-
ether informally to discuss game fish and game
sh research.

The cooperation of the billfish captain is most
nportant if adequate, meaningful scientific data
re to be collected. Scientists interested in billfish
esearch have only three methods of recourse to
ecure data: they can collect billfishes themselves,
highly expensive, time-consuming, and ineffi-
ient technique (especially since most scientists
re notoriously poor anglers!); they can rely on
ommercial longliners, who are invaluable, but
vho usually cannot supply data from coastal sport
ishing areas where longlining is sociologically off-
imits; or they can rely on a large number of sport-
ishing boats to gather quasi-synoptic data. For
his, the boat captain is indispensable.

he Angler

The billfish angler may be little more than a
awn as far as billfishing is concerned. In spite of
he payments he makes and the distances he
ravels to catch billfish, he is at the mercy of the
abits of the billfish, the expertise of the captain
nd mates, and the dependability of the fishing
oat. His expertise in most cases is not required to catch the billfish, for the captain finds the fish, and he and the mate tell the angler when and how to set the hook and how to fight the fish; the angler, essentially, merely reels, pumps, and reels, until the mate grabs the wire leader, then the bill, and then gaffs and boats the fish or releases it. Yet the skillful captain permits his angler to believe that he has caught the fish "all by himself." It is little wonder, then, that after one sailfish, the angler may become a self-styled expert, thereafter frequently suggesting to the captain how to run the boat and how fast to troll.

It is here that the scientist must rely on the boat captain to help him win over the angler to cooperate in supplying scientific data. A well-informed boat captain can convince the angler that he should tag and release his fish, or open the stomach, or bring the fish in for study. Only too often, anglers frustrate scientists' efforts to obtain a sufficient number of billfish for study because they believe "it's bad conservation" *not* to release. Thus, the scientist is deprived of the much-needed data which will enable him to determine what *is* "bad conservation" and an appropriate management program. Such cooperation requires the scientist to communicate his thoughts to the angler, as well as to the boat captain. Catch and effort data, economic information, logbook data, tagging information, and moral and financial support may all emanate from the billfish angler, but it is a matter of supplying information and education on the part of the scientist.

The Sportfishing Industry

As such, there is no real sportfishing industry in the sense that there is a commercial fishing industry. Sport fishing is represented by builders of boats, motors, rods, reels, tackle, lures, and various specialized gear for billfish such as fighting chairs, gin poles, and outriggers. There is no single, unified voice which speaks on behalf of this broad field. The American Fishing Tackle Manufacturing Association is extremely important, but represents only a small portion of the industry.

The single most important influence in the development of sport fishing, including billfish and their research and conservation, has been the Sport Fishing Institute, Washington, D.C. In its monthly *Bulletin,* it reports on latest research finds, angling activities, legislation important for sport fisheries, conservation programs, education in the aquatic sciences, and a host of other items. This Symposium may have had its roots with the Sport Fishing Institute, because it was this organization which met informally with Japanese negotiators in Brazil in May, 1966, at the height of the controversy between sport fishermen and Japanese longline fishermen, to reach peaceable, workable solutions. This meeting also focused attention on the need for much more biological, statistical, and economic data on billfish, which various research organizations have attempted to collect since that meeting.

Agencies such as the Sport Fishing Institute can act catalytically to bring together anglers, scientists, boat captains, commercial fisheries interests, and state, local, and national governments. They can promote the ideas for the development of new kinds of lures, sonic or optical teasers, better boats and navigational equipment, new kinds of baits, and scores of concepts which, if effected, would benefit everyone. Most of all, such an organization can promote good will among all factions and can help prevent much of the misunderstanding and distrust which frequently occurs when several kinds of exploiters are competing for the same resource.

The Multiple-use Concept for Billfish

Billfishes perhaps represent one of the ideal organisms to mankind. They are spectacular fighting fish for the angler, and their unpredictable leaps, jumps, skittering, greyhounding, and tailwalking have resulted in reverent terms for billfish acrobatics when they are being hooked and fought. When released, they give the angler a spiritual sense of gratification in having let a magnificent sea creature go, to swim again with its man-spared life, perhaps to take his or someone else's hook one day. Even better, a fish marked with a tag may be caught again, possibly a few miles away, or possibly several thousand miles away and several years from now, to give science valuable information on its habits.

When mounted by a taxidermist and, posed on the den wall, a billfish is a magnificent memento of a splendid day's action. The profit to the taxidermist is considerable, while the agent, who may be a boat captain, a mate, a dockmaster, as a specific task, receives a percentage of the taxidermist's cost, which averages about $2 per inch, which isn't really very much after one has spent perhaps a thousand dollars to get to the angling grounds.

A billfish caught by an angler and kept chilled or out of the sun is still available as food. Fresh billfish are excellent to eat and, depending on the species, range from fair to excellent as food. Billfish can be eaten fresh, smoked, canned, salted, baked, fried, curried, sautéed, or, especially, smoked. Smoked billfish is somewhat like Canadian bacon in flavor, and can be served as a staple food or hors d'oeuvres. Few fish are more adaptable or have fewer small bones for the connoisseur to discard.

Finally, after the fish is hooked, fought, landed, professionally photographed, skinned and mounted, smoked, and eaten, the last remnants of the fish—the bones and guts—still remain for the scientist to study. Billfish can, of course, be carefully and easily skinned so that the fish is intact for a taxidermist's mounting yet remains available for scientific study. In short, the billfish is the complete fish for the complete angler—something for everyone. To avoid excessive support for my taxidermist colleagues, I will avoid a discussion of the extremely valuable information which they freely supply to scientists, such as specimens, stomach contents, and gonad collections.

Thus, a billfish is truly a multipurpose fish, a sort of biological schmoo, as long as there are plenty of them to satisfy the needs of all legitimate interests while still maintaining the biological stocks. The rational utilization and management of these stocks must necessarily depend on scientific information derived from size composition, population estimates, and growth and mortality calculations. As long as the scientist believes that there are adequate biological stocks to support a sport and commercial fishery, then there appears to be no reason why billfish can not be utilized for as many human-oriented uses as possible, other factors being equal. Billfish as food, as taxidermists' mounts, and as scientific specimens should thus be utilized, either by catching, mounting, studying, and eating them or by tagging and releasing them. It is here, especially, where a cooperative management and marketing program, or both, is needed on the part of anglers, the sport fishing industry, guides and captains, and governments. The best use for a resource is rational economic and biological exploitation, rather than "blind" conservation (de Sylva, 1957).

The ever-present problem in billfish research deals with conservation versus aesthetics. Scientists may hate to see a magnificent marlin brought in to the dock, hung on a hook for photography, and allowed to rot, while anglers feel exactly the same way. Yet both groups are displaying emotions. The scientist must determine if such a demise for large marlins is biologically deleterious to the stock, while the angler should analyze if his indignation against desiccated sailfish hanging on a rack is not really the feeling for virtue, aesthetics, and sportsmanship. Thus, we are faced with conservation versus aesthetics: we must not confuse the two concepts. It is perfectly justifiable to release a dozen sailfish, even though they are already senescent, for sportsmanship purposes, in hopes that you may catch them again or, if they are tagged, that you will catch one of your own tagged fish. But one must be careful not to confuse aesthetics with conservation. Conservation means the wise utilization of existing stocks, based upon scientific evidence, whereas aesthetics reflect how the angler *feels* emotionally toward the same stock, without benefit of adequate scientific evidence. All too often our sport fishery for billfish, and many other resources, has been regulated, legislated, and dominated by aesthetic criteria rather than by scientific facts.

Billfishes can and should be used by many persons and countries. These countries, and their alleged factions of sport and commercial billfishermen, tackle manufacturers, and boatmen, require a well-coordinated regular program based on scientific evidence which is, in turn, based upon goals mutually decided upon by scientists, anglers, boat captains, commercial fishermen, and outdoor writers. Such programs could include tagging, stomach analysis, gonad collection, and collection of environmental information based upon data required by scientists. Unless we obtain adequate scientific information on this valuable resource, we may be faced with Orwellian national and international regulations that none of us can accept.

The Billfish Tournament

Friendly competition among men, as exemplified by amateur sports, initially was intended to test comparative feats of skill, strength, and endurance. But the tournament may bring out the best and the worst in all of us, and sometimes we forget *why* we are fishing. The lure of prize money or trophies frequently affects man, and his actions are not always what his original intentions were. Billfish tournaments usually involve strict rules of trolling, bait usage, chumming, line tests, and method of release, and an angler, or even his captain or mate, may be tempted to overlook these rules if it seems expeditious in order to win a tournament. While the competitive sport of winning is important, it perhaps should not be reflected in trophies for the anglers and money for the winning crew. An ideal tournament to discourage bad sportsmanship is perhaps where everyone wins a first prize.

Tournaments have many advantages, however. Anglers and captains have a chance to test their skills, new tackle, and their Sportfishermen under severe conditions imposed by intense fishing. The comradeship at cocktail hour is perhaps underestimated, for here old acquaintances are met and new friendships made. These happy hours are especially auspicious for the scientist, for here he can informally exchange information with anglers, captains, and crew. Tournaments are also important in that during a short period of time, a large number of fish may be brought in for research for scientific observations, or a great many billfishes can be tagged and released, or a considerable number of nearly synoptic observations can be made by anglers and captains on the fishing grounds. Successful tournaments are frequently those in which angling and science work together, especially when the angler and captain feel that they are contributing something to science which may improve their billfishing some day. The Hawaiian International Billfish Tournament is an outstanding example of such cooperation.

The Role of Local, State, and National Governments

Governments can benefit from encouraging billfish angling in their waters because of the revenue brought in by an angler and spent on boat charters, hotel, food, and, especially, alcohol, airline travel, car rental, and souvenirs, as well as miscellaneous funds spent by his family which may accompany him. Increasingly, more airways are including big-game fishing as part of a package tour for a vacation. Underwriting costs could be done by governments for the acquisition and development of better sportfishing vessels, docks, fueling facilities, bait collection and storage, and exploratory angling for new fishing grounds. Such costs can seldom be borne by individual boat captains. Governments can offer incentives for the training of capable fishing mates, and can reduce the high import taxes on boats, gasoline, and tackle used in angling.

All levels of government should be concerned with protecting their valuable fisheries resources, as well as developing them. Outmoded laws should be re-evaluated and replaced with laws based on current scientific findings. For such reasons, it is important for the governments to work closely with scientists. Also, anglers and boat captains are seldom represented at government levels or are advisors to them. Finally, all levels of government should support scientific research, exploratory fishing, and the development of angling for billfish. More cooperation is needed among the anglers, scientists, and governments. Possibly here is where private organizations such as the Sport Fishing Institute can be a catalyst to motivate cooperative efforts.

The Scientist

The greatest hindrance to the development of billfish research has been the scientist, partly because of lack of funds and partly because of a lack of interest. With the exception of the Japanese research programs, there have been no well-funded, long-term, or comprehensive studies on billfishes. Most scientific publications on billfish have been done on a financial shoestring or are a spinoff pirated from another project. Anglers, commercial fishermen, boat captains, and scientists must urge that adequate funds be made available for long-term comprehensive studies. A scientist must convince funding agencies that research on billfish is needed; he can be aided morally by anglers, captains, commercial fishermen, the sport fishing industry, and local governments in his quest for support. And, most important, the scientist must clearly communicate his research interests with the granting agencies, as well as the persons from whom he seeks collateral support. During these studies, if he receives financial support, he is continually obliged to report his findings—including those relating science and billfishing—to the sportsmen, boat captains, and the sport fishing industry in understandable language. Supporters of billfish research want and deserve results.

What are some of the directions billfish research should take? The pure scientist should rightfully be interested in billfish systematics and evolution, reproduction and development, behavior, food and feeding, life history, ecology, and any facets of the broad fields which he wishes to pursue.

It is presently impossible with our knowledge and facilities to capture, transport, and maintain in capitivity an adult billfish. However, behaviorists using submersibles and even scuba should attempt to study the daily activities of billfish in their natural habitats including their horizontal and vertical migrations. Such observations might offer clues to the visual and olfactory senses of billfish, information which would be valuable to billfish anglers. Rearing of eggs and larvae can probably be done to at least the juvenile stage, and such information should reveal valuable information on the physiological requirements and behavioral ecology of billfishes.

Tagging studies should be intensified to include tagging of smaller specimens of billfish (i.e., those with a potentially longer life span ahead of them) concomitant with genetic and morphometric studies of subpopulations. By studying catch rates from anglers' logbooks and tournament records, fluctuations in catch per unit of effort can be detected.

The problem of the fishing grounds has already been discussed, but this problem should be reviewed here to stimulate further study.

Environmental (i.e., physical, chemical, and biological) information should be obtained about billfish habitats, including information on environmental fluctuations, hopefully at the same time span and in the same areas that biological data are being gathered on billfishes. Knowledge of temperature, salinity, turbidity, density, thermocline structure, and plankton patterns in relation to billfish distribution can be jointly analyzed by biologists and physical oceanographers.

The effects of pollution on billfishes should be studied, including the transfer of contaminants through the food web. Heavy metals, chlorinated hydrocarbons (including DDT and PCBs), sewage and industrial wastes, various hydrocarbons and their fractions, and radionuclides may adversely affect billfish at some stages of their life history, or may interfere sublethally with metabolic processes, such as reproduction or migrations. Finally, man-made contaminants may build up via the food web to high concentrations in various parts of billfish flesh, at which levels they are a potential hazard to the human consumer.

Who is going to do all this work? There are already many needy research projects going unsolved and unfunded. The problem is particularly difficult with the hard-to-study big-game fishes because of the expense and time involved, and the good possibility that the investigator will end up with few or inconclusive data. Hence, this type of study is likely to be done by a technician working 8 a.m. to 5 p.m. during the week, and it is virtually impossible to study billfish on such a schedule. The alternative is to attract imaginative young students to these problems. Yet, few students will embark upon a master's or doctoral program unless there is *some* assurance that they will obtain their degree in a reasonable time, and that the results, even though negative, will be scientifically acceptable. It has been my experience that few students will attempt theses as risky as those involved studying the unpredictable billfish. One answer may be in providing adequate funds to senior investigators who can conduct long-term research and relegate a small portion of that research to their students for a suitable graduate degree.

Once all of this research has been completed, how does it relate to the angler, the boat captain, and the management of the resource? The biological and environmental data, used judiciously, can serve as management tools. Through cooperative studies which actively *involve* the angler and boat captain, the scientist can obtain biological, statistical, and environmental data. Such data can be valuable to the angler and boat captain, for the scientist may be able to make reasonably accurate forecasts of when and where the billfish angler should fish, at what depth, at what time, using what kind of bait, and at what trolling speed. These are not unreasonable demands of the angler to make of the scientist.

Scientists should also work with the boat captain and the sportfishing industry in the application of behavioral principles in developing new kinds of artificial lures which utilize the visual or sonic responses of billfish, or in developing of artificial floating habitats which might attract and concentrate billfish. This scientific information should be sorted out in such a way as to be meaningful for the layman to understand the fish they seek, and possibly to catch more billfish or even to be able to catch billfish when no one else can. To date, marine science has greatly aided commercial fisheries, but there are few instances where marine science has contributed practical solutions to the anglers' problems.

The key words are cooperation and advice which will benefit all parties without damaging the billfish resources. A first step is to determine *if* commercial fishermen can continue to take large quantities of billfish without depleting the resource or reducing the billfish sport fishery catch. A second point is that environmental degradation favors neither sport nor commercial fishermen. All persons interested in billfishes and billfishing must work together openly and intelligently, as we have done at this Symposium, to resolve alleged differences among ourselves, to abate marine pollution, and to urge more research and intelligent communication.

POSTSCRIPT

The foregoing discussion of the billfish, boats, gear, angling methods for billfish, and the future pertains to the most successful kind of billfish angling. Yet we know that such expense and time can only be enjoyed by a small percentage of recreational fishermen in a small part of the world. Parenthetically, we may ask ourselves *why* we need or even tolerate such expensive pleasures in a world fraught with hunger, disease, hatred, and war? Possibly, we may reply, if we had the option for *some* form of relaxation, from throwing pebbles in the pond in Iowa to trolling for black marlin off Australia, that such relaxation regardless of expense, could enable us to be at peace with ourselves and our fellow men. One may argue whether we really *need* something as expensive as angling for billfish. But how many of us, either as oceanographers, or anglers, or plumbers, or book clerks, rest our Mitty-like hopes and imagination in defeating the invading Mongol hordes, or in subduing the Nile crocodile, or in orbiting the moon, or—something with which all of us can identify—in landing that monster blue marlin off Tahiti that Zane Grey once told us about?

ACKNOWLEDGMENTS

The late Colonel John K. Howard was especially helpful in supplying information and data on sport fishing for billfish in all parts of the world. The late Albert Swartz and Al Pflueger, Sr., and Richard H. Stroud and Paul E. Thompson gave freely of their time and suggestions.

This research was supported in part by the Bureau of Sport Fisheries and Wildlife, Contracts BSFW 14-16-0008-775/DI-14-16-0008-957, and the Maytag Chair of Ichthyology, University of Miami.

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The Paleontology of Billfish—The State of the Art

HARRY L. FIERSTINE[1]

ABSTRACT

The major osteological features are described for living billfishes. All billfish remains are reviewed critically and some questionable forms are placed in Xiphioidei Incertae Sedis (uncertain status). The remaining xiphioids are placed into three families: Istiophoridae, Xiphiidae, and Xiphiorhynchidae. A new undescribed xiphiid from Mississippi shows that the billfish lineages must have diverged prior to the Eocene. Areas of research are suggested that will help place the paleontological studies on a more secure foundation.

Although billfish fossils have been known for over 130 yr (Agassiz, 1838), Regan (1909) and Berg (1940) have been the only ones to summarize the paleontological knowledge of this important group. This paper reviews all fossil groups that are generally considered to be billfish and separates the questionable from the unquestionable forms. In order to put the paleontological and phylogenetic discussion on a firm foundation, I have summarized some of the major osteological features. In addition, I have pointed out some areas of research that will aid future paleontological studies.

OSTEOLOGICAL INFORMATION

Since crania, rostra, and vertebrae are the most common billfish structures found in the fossil record, the following review of recent osteology will emphasize them.

Various authors (Gregory and Conrad, 1937; Nakamura, 1938; Nakamura, Iwai, and Matsubara, 1968; Ovchinnikov, 1970) have shown that the rostra, skull, and vertebrae differ greatly between the Xiphiidae (swordfish), on the one hand, and the Istiophoridae (marlin, sailfish, and spearfish), on the other hand. In general, the skeleton is lighter and less ossified in the Xiphiidae than in the Istiophoridae. The swordfish (Fig. 1) has a flattened rostrum, a short occipital region of the skull, and a one-piece lower jaw without a symphyseal joint. The istiophorids (Fig. 2) have a rounded rostrum, a comparatively longer occipital region, and a lower jaw with a predentary bone and a symphyseal joint. The vertebrae (Fig. 3) of the swordfish (when compared with the istiophorids) lack the overlapping processes, the centra are more cube-like than elongate, and the caudal skeleton (Fig. 4) has more separate bones (Fierstine and Applegate, 1968; Fierstine and Walters, 1968).

Comparative osteology has been little help in distinguishing between the various members of the family Istiophoridae. *Tetrapturus* and *Istiophorus* have 12 + 12 = 24 vertebrae and *Makaira* has 11 + 13 = 24 vertebrae. Since only isolated vertebrae have been found in the fossil record for istiophorids, this vertebral difference has not been useful to paleontologists. In general, there is generic similarity in bone morphology. In *Makaira* the bones are usually more massive than the other genera and the vertebral centra are much wider anteriorly (Fig. 5) than posteriorly (Nakamura et al, 1968).

The bones of the branchial apparatus and limb girdles have been studied by Nakamura (1938) and Nakamura et al (1968), and they have very briefly discussed the similarities and differences between the various species. These studies will prove useful when complete fossil skulls of istiophorids are found or when individual bones are recognized.

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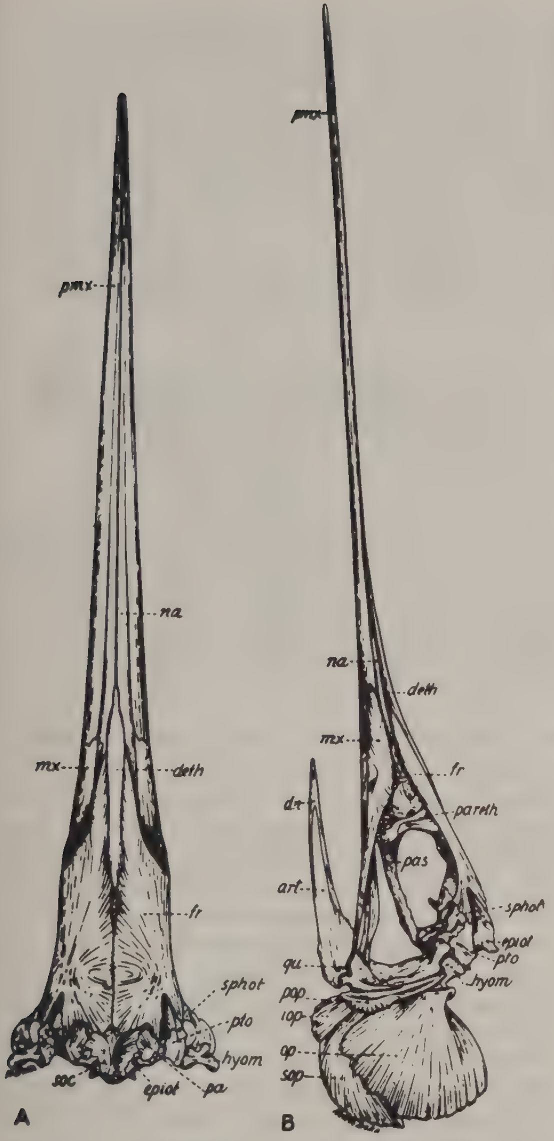
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Figure 1.—Swordfish *(Xiphias gladius)* skull. **A.** Dorsal view. **B.** Lateral view. (From Gregory and Conrad, 1937.)

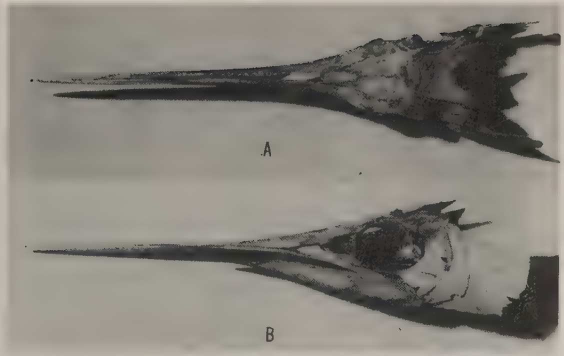
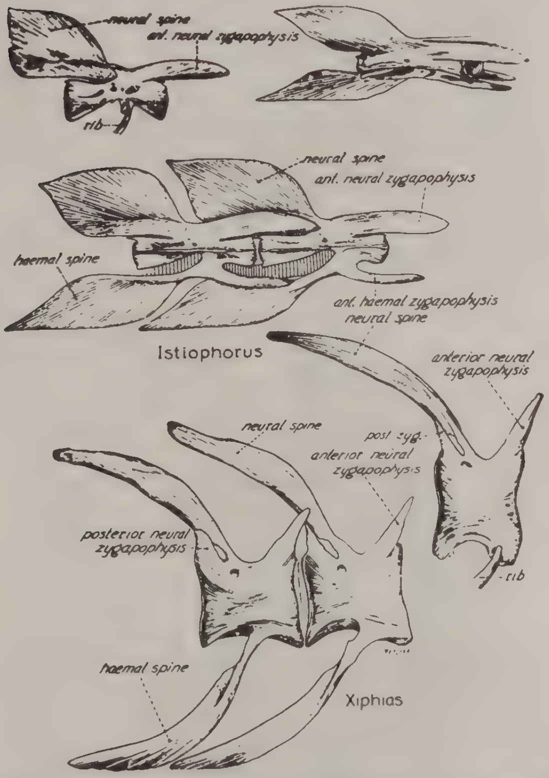


Figure 2.—Striped marlin *(Tetrapturus audax)* skull. **A.** Dorsal view. **B.** Lateral view.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neural spine
post zyg.
anterior neural zygapophysis
posterior neural zygapophysis
rib
haemal spine
Xiphias

Figure 3.—Trunk vertebrae of billfish. (From Gregory and Conrad, 1937.)

REVIEW OF THE FOSSIL RECORD

Generally, taxonomists (Berg, 1940; Regan, 1909; and Romer, 1966) recognize five billfish families: Blochiidae, Istiophoridae, Paleorhynchidae, Xiphiidae, and Xiphiorhynchidae. I will use these families as a starting point for the following discussion. I agree with Gosline (1968, 1971) that these families should be placed in their own suborder, the Xiphioidei, within the Order Perciformes. I have neglected to include the family Luvaridae within the Xiphioidei because I do not believe it belongs there (it has a peculiar vertebral column and no rostrum) and because it has no fossil record.

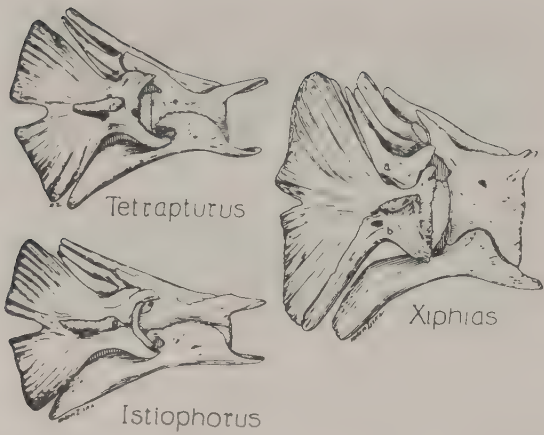


Figure 4.—Caudal skeletons of billfish. (From Gregory and Conrad, 1937.)

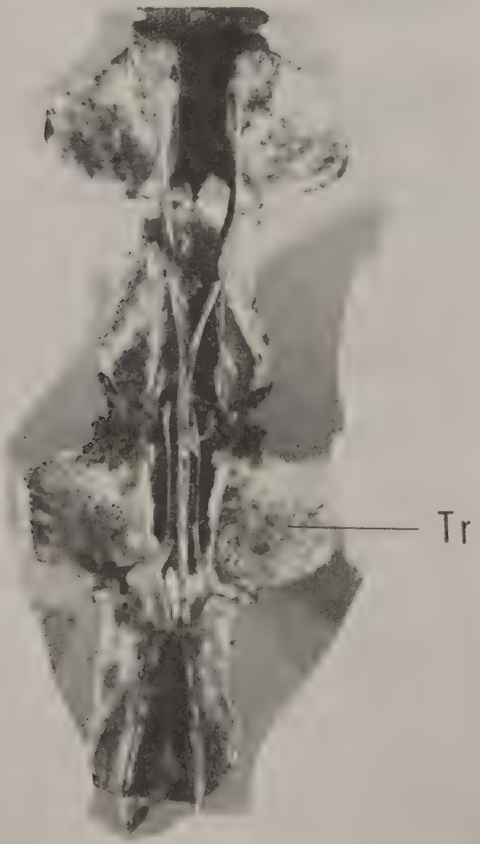


Figure 5.—Two successive caudal vertebrae from a black marlin *(Makaira indica)* showing the transverse flanges (Tr) that project from each centrum.

The Blochiidae contains two distinct fossil forms, *Blochius longirostris* and what I call the "*Cylindracanthus* group". Complete skeletons of *Blochius* (Fig. 6) have been found in the Lower Eocene deposits of Monte Bolca, Italy. The skeletons are about 1 m long and exhibit many billfish characters such as: a round and elongate rostrum, a low vertebral number, elongate vertebrae, and a deeply forked caudal fin. To the best of my knowledge no one has critically studied *Blochius* since Woodward (1901) published his catalogue of fossil fishes.

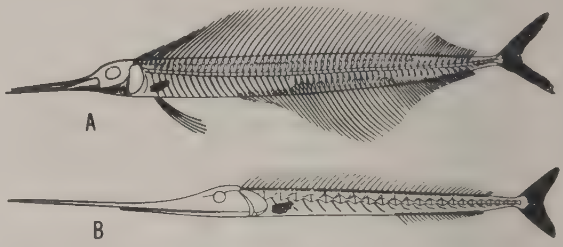


Figure 6.—**A.** Reconstruction of *Paleorhynchus glarisianus*. **B.** Reconstruction of *Blochius longirostris*. (From Gregory and Conrad, 1937; after Woodward, 1901.)

The "*Cylindracanthus* group" *(Aglyptorhynchus, Congorhynchus, Cylindracanthus, Glyptorhynchus, Hemirhabdorhynchus,* etc.) are all known by small, cylindrical, elongate structures (Fig. 7) that are thought to be rostral fragments of a *Blochius*-like fish (Carter, 1927). A few vertebrae have been attributed to the "*Cylindracanthus* group" because they were found associated with the rostra (Leriche, 1910), but the evidence that they belong to the "*Cylindracanthus* group" is simply circumstantial.

In order to tidy up the billfish classification, I have chosen (Fierstine and Applegate, in press) to put the "*Cylindracanthus* group" and *Blochius* into the Xiphioidei Incertae Sedis. Although the establishment of a category with uncertain affinities avoids the responsibility of making a precise taxonomic decision, it emphasizes our lack of knowledge of its members.

The Istiophoridae contains the living genera *Istiophorus, Makaira,* and *Tetrapturus,* and the fossil genera *Brachyrhynchus,* and possibly *Acestrus. Acestrus* (Fig. 8) is only known from the Early Eocene and the remains consist of the posterior part of skulls. Casier (1966) felt that these crania belonged to a billfish, but he also noted the similarity to the extinct scombrid, *Scombrinus*. The cranial fragments of *Acestrus* are quite small, only 50-60 mm

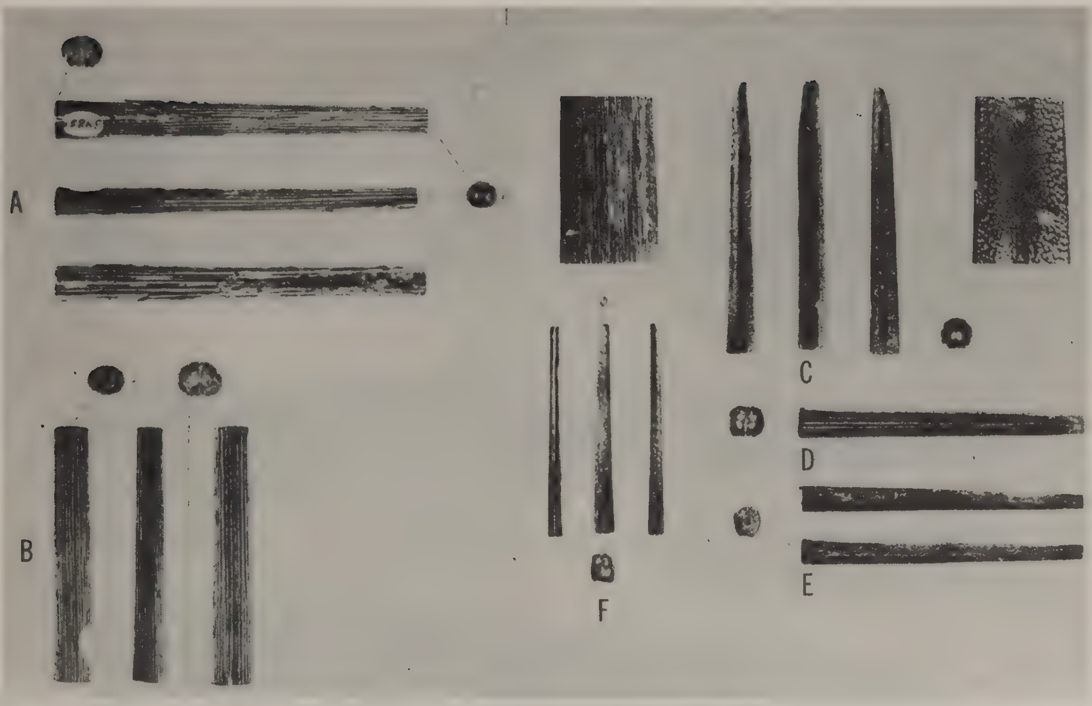


Figure 7.—Rostra of the "*Cylindracanthus* group" **A, B.** *Cylindracanthus rectus*. **C, D, E.** *Aglyptorhynchus venablesi* **F.** *Aglyptorhynchus sulcatus*. (From Casier, 1966.)

in length. It is possible that these small skulls belong to one of the small spearfishes. Three species of *Brachyrhynchus* have been described from rostra found in the Eocene of Belgium and the Pliocene of Italy. Woodward (1901) thought that *Brachyrhynchus* was probably identical with *Istiophorus*. Based upon the figures that I have seen, I agree that *Brachyrhynchus* belongs to an extant genus of the Istiophoridae.

Most paleontologists (Woodward, 1901; Leriche, 1910; Casier, 1966) seem to have lumped all living istiophorid species into a single genus *(Istiophorus* or *Tetrapturus)* and to the best of my knowledge, Fierstine and Applegate (1968) have been the only paleontologists to try to place the fossils into one or more of the three extant genera. Our attempt was not too fruitful because of the lack of comparative osteological studies on the living forms. Nevertheless, we recognized a predentary bone and a rostrum (Fig. 9) from the Miocene of California as belonging to *Makaira* sp. The identifications were based on the fact that these structures were much larger and more massive than the similar structures in *Istiophorus* and *Tetrapturus*.

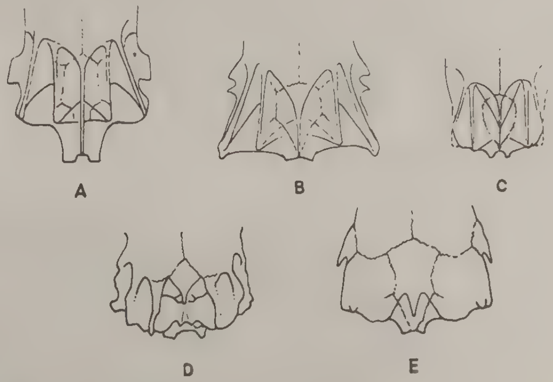
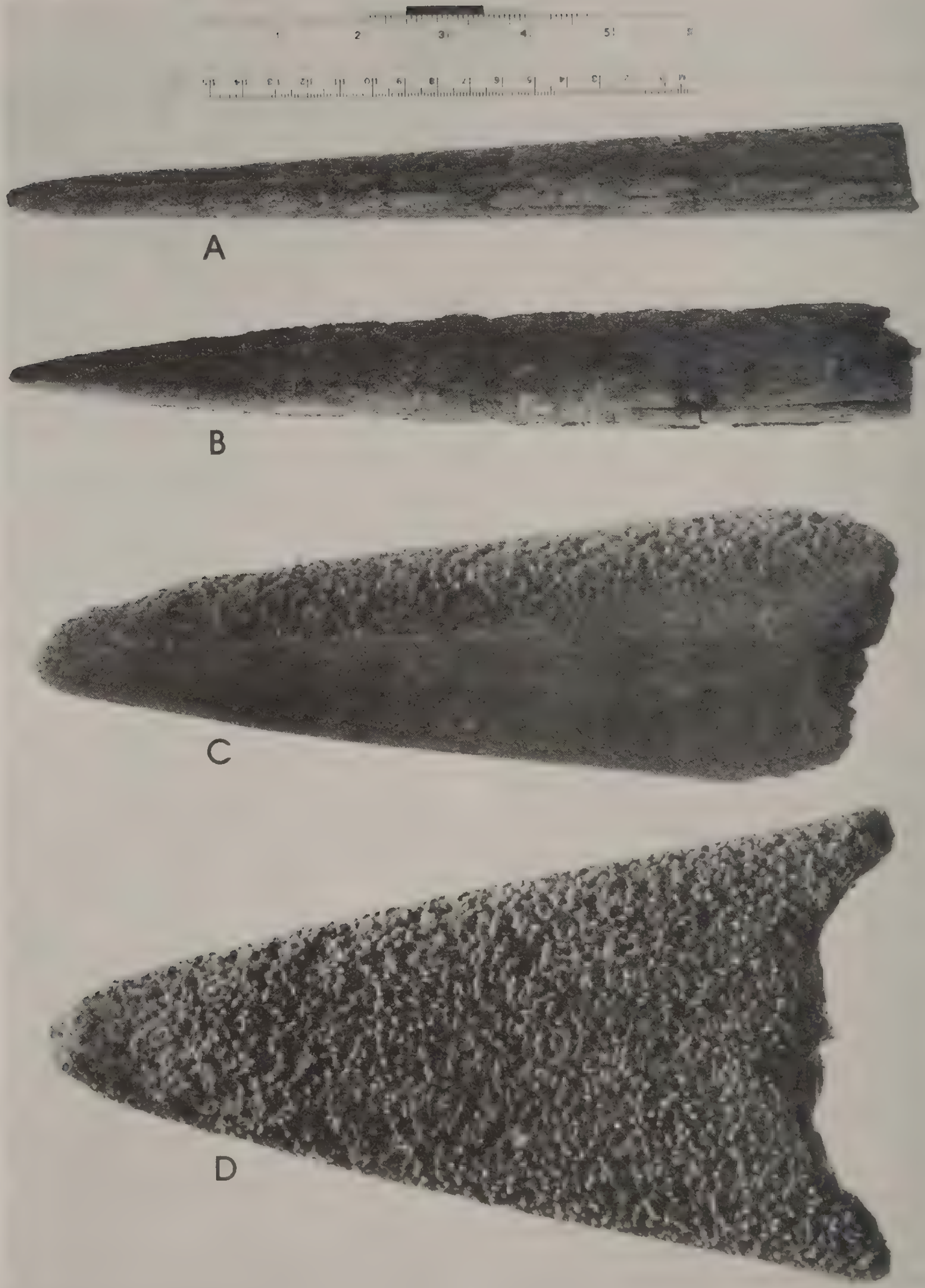


Figure 8.—Diagrams of the occipital region of several scombroids and xiphioids. **A.** *Wetherellus*. **B.** *Scombrinus*. **C.** *Acestrus* sp. **D.** *Acestrus ornatus*. **E.** *Xiphiorhynchus*. (From Casier, 1966.)

Figure 9.— *Makaira* sp. from the middle Miocene of California. Rostrum, lateral view **(A)** and dorsal view **(B)**. Predentary, lateral view **(C)** and dorsal view **(D)**. (In part from Fierstine and Applegate, 1968.)


A
B
C
D

The Paleorhynchidae (Fig. 6) comprises five genera *(Enniskillenus, Homorhynchus, Hemirhynchus, Paleorhynchus,* and *Pseudotetrapturus)* that are found from the Eocene to the Oligocene of Europe. One species, *Pseudotetrapturus luteus,* reaches up to 4 m in length (Danil'chenko, 1960), although other species usually are no longer than 1 m in length. Their vertebral count varies from 45 to 60. According to Danil'chenko (1960), *P. luteus* resembles *Tetrapturus* in dimensions and body form and in the structure of the elongated snout, but it differs from *Tetrapturus* in the far greater number of vertebrae, the much longer lower jaw, the more dorsal position of the pectoral fins, and the presence of large scales. Since I feel that the resemblances to the istiophorids are probably a result of convergence, I choose to put them in the Xiphioidei Incertae Sedis.

The family Xiphiorhynchidae is known from five species found in the Eocene of Africa, America, and Europe. The original description was from cranial fragments and subsequently various rostra were thought to be conspecific with the cranial fragments (Woodward, 1901). The crania (Fig. 10) are similar in proportions to those found in the Istiophoridae. Recently the Los Angeles County Museum of Natural History was given a large rostrum and two associated vertebrae (Figs. 11, 12) which belong to a new species of *Xiphiorhynchus* (Fierstine and Applegate, in press). One vertebra, an abdominal, is similar in size and shape to an abdominal vertebra of a black marlin *(Makaira indica),* whereas the other vertebra, a caudal, is similar in shape to that of a swordfish. Both vertebrae are strongly ossified like

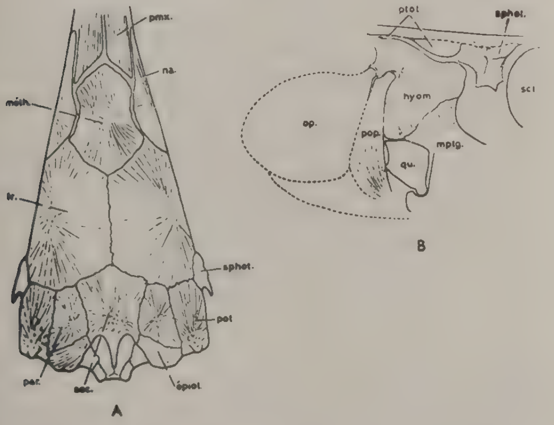


Figure 10.—Semidiagrammatic reconstruction of *Xiphiorhynchus priscus.* **A.** Dorsal view of skull. **B.** Lateral view of opercular region. (From Casier, 1966.)

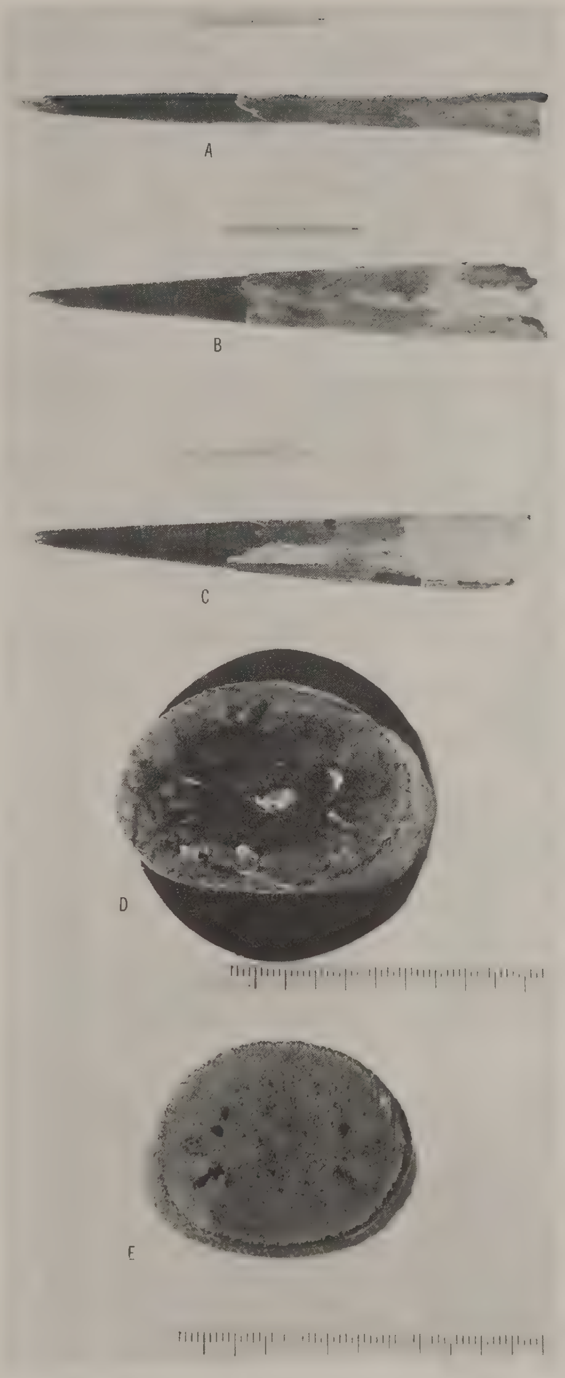


Figure 11.—Rostrum of *Xiphiorhynchus* sp. from the Eocene of Mississippi. **A.** Lateral view. **B.** Dorsal view. **C.** Ventral view. **D.** Cross-section taken 220 mm from distal tip. **E.** Cross-section taken 170 mm from distal tip.

those of the Istiophoridae. The large rostrum is similar in size and shape to that of the genus *Makaira* except that it is more flattened at its base. In cross-section, the xiphiorhynchid bill (Fig. 11) has a central longitudinal nutrient canal as well as two or more pairs of lateral nutrient canals. Istiophorids have only one pair of lateral longitudinal canals and lack a central canal. Xiphiids have a central longitudinal canal with only one pair of lateral canals. In short, this new species of *Xiphiorhynchus* seems to be intermediate to both the Istiophoridae and the Xiphiidae.

The Xiphiidae has a poor fossil record and this may be due to the poor ossification of its bones. Leriche (1910) identified one caudal vertebra from the Oligocene of Belgium as *Xiphias rupelensis* and it is similar to the hypural plate of *Xiphias gladius*. Most references to fossil Xiphiidae refer to the "*Cylindracanthus* group" or to the Istiophoridae. Recently Shelton Applegate of the Los Angeles County Museum of Natural History found a rostrum in the Eocene of Mississippi. It is 750 mm long, is depressed, and has a cross section at its base similar to a double-bladed axe. Distally the sharp lateral edges become blunt and the edge has a scalloped margin. Although the rostrum is unique, I strongly feel that it belongs to an yet unknown xiphiid.

In summary then, the classification of billfish should be:

- ORDER PERCIFORMES
  - SUBORDER XIPHIOIDEI
    - FAMILY ISTIOPHORIDAE (? *Acestrus, Brachyrhynchus, Istiophorus, Makaira, Tetrapturus)*
    - FAMILY XIPHIORHYNCHIDAE *(Xiphiorhynchus)*
    - FAMILY XIPHIIDAE *(Xiphias,* and undescribed Eocene genus)
  - XIPHIOIDEI INCERTAE SEDIS
    - FAMILY PALEORHYNCHIDAE *(Enniskillenus, Hemirhynchus, Homorhynchus, Paleorhynchus, Pseudotetrapturus)*
    - FAMILY BLOCHIIDAE *(Blochius,* ? "*Cylindracanthus* group")

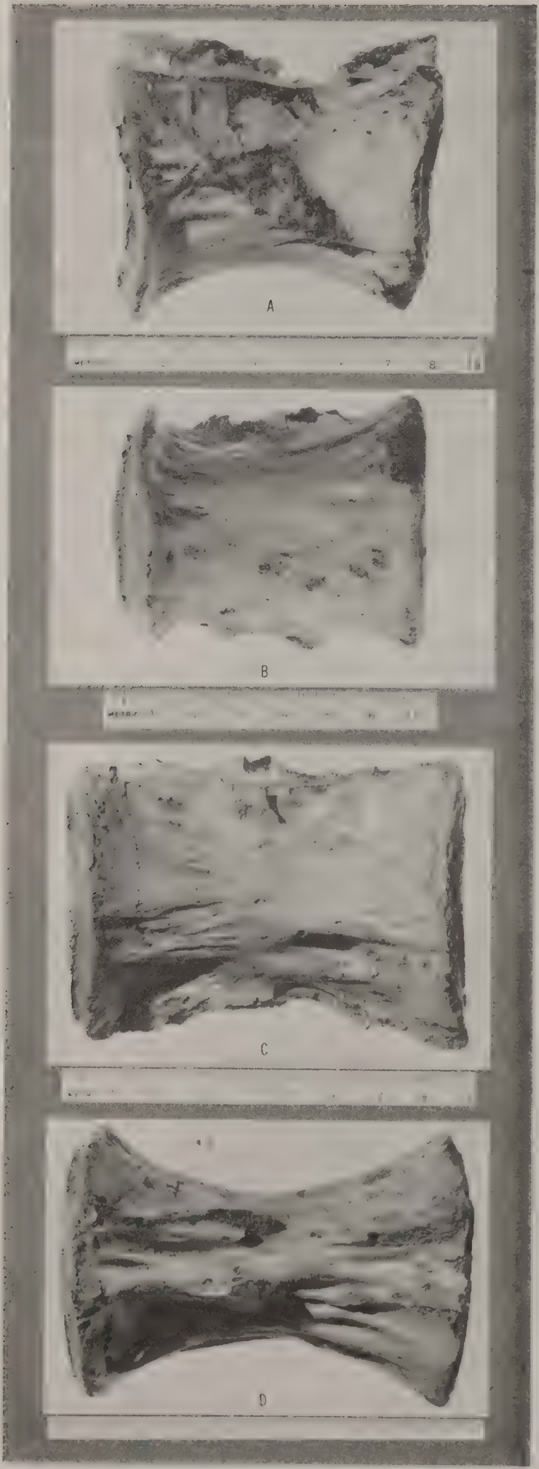


Figure 12.—Two vertebrae of *Xiphiorhynchus* sp. from the Eocene of Mississippi. **A.** Lateral view of abdominal vertebra. **B.** Ventral view of abdominal vertebra. **C.** Lateral view of caudal vertebra. **D.** Ventral view of caudal vertebra.

At this time it is difficult to propose any phylogenetic scheme. Evidence seems to suggest that at least three billfish groups had differentiated and were living contemporaneously during the Eocene. Members of the recent genera were living in Miocene seas and they may be conspecific with those that are alive today. Whatever form was the common ancestor to the istiophorid and xiphiid lineages had to be in existence prior to the Eocene.

AREAS OF RESEARCH

Comparative osteological studies on recent billfish are needed in order to reasonably evaluate the fossil forms. Good osteological collections are rare because museums and universities lack the necessary storage space; thus they usually avoid the preparation of large skeletons. Therefore, my first suggestion would be for more skeletons. A study of the relative size and dimensions of the rostra and vertebrae would be very useful. Since these structures are usually found separate from the rest of the skeleton, simple comparative morphometric data would aid their identification. Even though paleontologists have placed importance on the histology of fossil bills, the placement and number of nutrient canals and the structure of the denticles are not known for many of the recent forms.

The functional anatomy of the feeding apparatus and the method of locomotion are not known. For example, the function of the predentary bone has been surmised (Fierstine and Applegate, 1968) and the role of the bill itself is just conjecture (Wisner, 1958; Tibbo, Day, and Doucet, 1961). The presence of the predentary bone may be an adaptive feature for large "slab-sided" fish with elongated upper or lower jaws. Aspidorhynchid holosteans (Fig. 13) have a predentary bone (Orlov, 1964; Zittel, 1932) and the extinct clupeiform suborder Saurodontoidei has an edentulous predentary which extends the lower jaw well beyond the upper (Bardack, 1965). Neither of these groups are thought to be directly related to each other or to the istiophorids (Greenwood, Rosen, Weitzman, and Myers, 1966; Gosline, 1968, 1971).

No one has reliably measured the swimming speed of a billfish or analyzed their swimming movements. It is fairly obvious that the size and behavior of these fish are difficult barriers, but they could be overcome. A better understanding of the feeding and locomotory apparatuses would help us explain the differences between the istiophorids (rounded bill, predentary bone, elongate centra with overlapping processes, fused caudal skeleton) and the xiphiids (depressed bill, no predentary bone, cube-like centra with no overlapping processes, no pelvic fins).

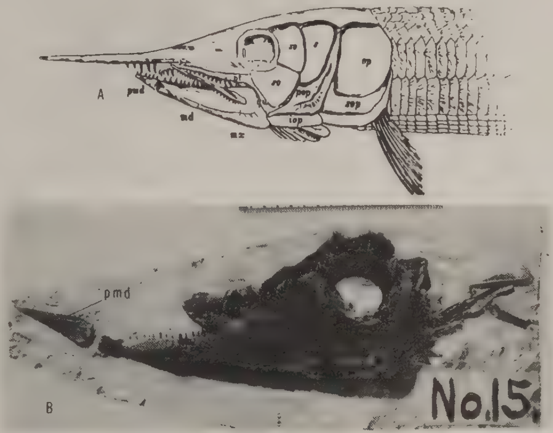


Figure 13.—Two other examples of fish with predentary (pmd) bone. **A.** *Aspidorhynchus acutirostris* from the Jurassic of Solenhofen, Germany. (From Zittel, 1932.) **B.** Unidentified saurodontid. Age (probably Cretaceous) and location unknown.

The European fossil billfish need to be studied by someone who is familiar with the recent forms. There is no fossil group that does not need review. What is *Brachyrhynchus*? Is it a synonym of some recent istiophorid? Is *Acestrus* an istiophorid? Paleorhynchids are now well-known from Russia (Danil'chenko, 1960). Their large size and body shape may be adaptive features that result from convergence and are not a result of any relationship to the xiphioids. Since their upper and lower jaws are nearly equal in length, the paleorhynchids remind me of a huge needlefish (Order Beloniformes). Are the smaller paleorhynchids just the juveniles of the much larger *Pseudotetrapturus luteus*? If nothing else, the quality of the illustrations of *P. luteus* needs to be improved.

The study of *Blochius* would be especially rewarding. Of all the uncertain groups, it seems to be the most likely candidate to be included in the Xiphioidei proper. Dr. George Myers (pers. comm.) once told me that *Blochius* had a predentary bone. No mention is made of this structure in the literature. In addition *Blochius* needs to be redrawn, as all available figures stem from a diagrammatic line drawing in Woodward (1901).

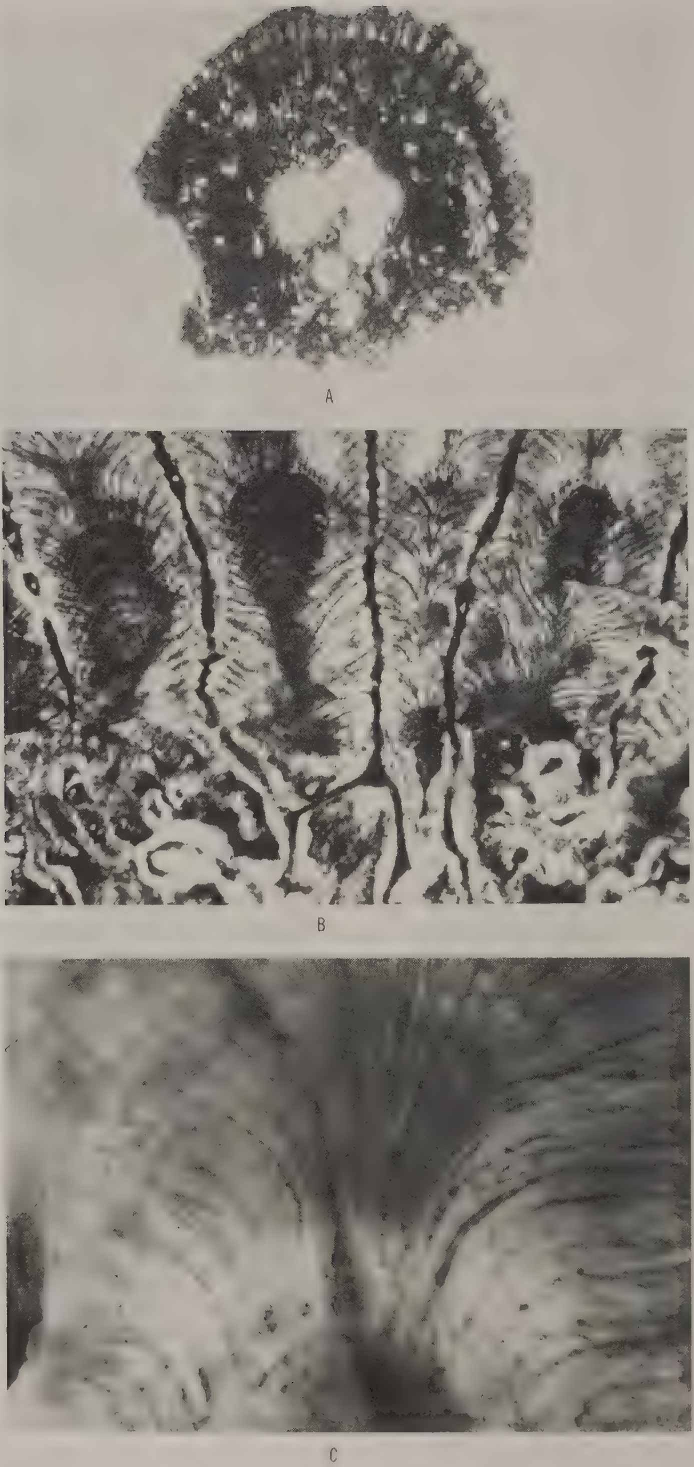


Figure 14.—Cross-section of a rostrum of *Glyptorhynchus* sp. from the Miocene of California. **A.** Low power. **B.** Medium power. **C.** High power.

The "*Cylindracanthus* group" is currently in taxonomic chaos. Casier (1966) divided the group into two parts; he placed one group in the family Blochiidae of the Order Heteromi (=Notacanthiformes) and the other group in the family Xiphiidae of the Order Scombromorphi (=?Scombroidei). No explanation was given as to why there was a relationship to the Order Notacanthiformes. Carter (1927) showed that a *Cylindracanthus* rostrum was similar histologically to a bill fragment of *Blochius* and he also showed that it was similar to a spine of the living trunkfish, *Ostracion*. Does this mean that the *Cylindracanthus* structures are bills or spines? What other structures would have a similar histology? The microscopic interpretation is very equivocal. Carter (1927) stated that the *Cylindracanthus* rostrum was composed of dentine. Tor Orvig (pers. comm.) interpreted *Cylindracanthus* bills to be composed of acellular bone. Rainier Zangerl (pers. comm.) interpreted a photomicrograph (Fig. 14) of a ground thin section of a *Glyptorhynchus* rostrum as dentine whereas, Melvin Moss (pers. comm.) has suggested that the same structure is composed of acellular bone.

The rostra of the "*Cylindracanthus* group" are characterized by two or more rows of "alveoli" (Fig. 15) on one surface, the supposed ventral surface. The "alveoli" are thought to have contained denticles, but no tooth-like structures have ever been present. I personally think that most, if not all, of the "*Cylindracanthus* group" rostra will prove to be fin spines. These structures are too numerous and common in the fossil record for each to represent an individual fish.

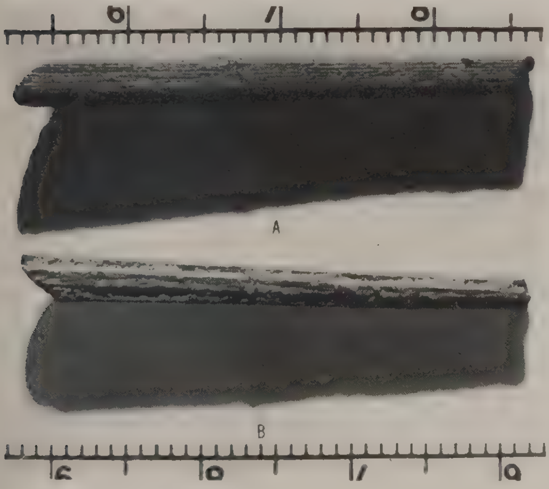


Figure 15.—Rostrum of *Glyptorhynchus* sp. from the Miocene of California. **A.** Lateral view. **B.** Ventral view showing two alveolar grooves.

Much of our lack of knowledge of fossil billfish stems from the paucity of comparative anatomical studies. Once this foundation is built there are many intriguing problems to solve in the fossil record. It is my hope that this paper has served as a stimulus for others to enter an uncrowded research field.

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Some Aspects of the Systematics and Distribution of Billfishes

IZUMI NAKAMURA[1]

ABSTRACT

Until recently the classification of billfishes (Xiphiidae and Istiophoridae) was confused. Recent workers have consolidated the nominal species and reduced the number of species considerably. A key, with figures, is presented which includes two families, four genera, and 11 species. *Makaira mazara* is considered distinct from *M. nigricans* because of consistent differences in the pattern of the lateral line system. *Tetrapterus platypterus* is tentatively separated from *T. albicans* although existing differences are minor and could be referable to the subspecific level. The worldwide distribution of billfishes is given; distributions are based primarily on data from the Japanese longline catch for 1964-69.

Despite their importance to sport and commercial fisheries and the large size attained by many of them, the fishes of the superfamily Xiphiicae (families Xiphiidae and Istiophoridae) have been little understood and until recently their systematics have been highly confused. The separation and nomenclature of the species of billfishes has been a difficult problem; this arises partly because the structure and characteristics of some ''species'' are quite similar, and also because the original description of most of the species has been inadequate. Thus, it is impossible to identify the different species immediately from the original descriptions.

Goode (1880, 1882) classified the billfishes of the world into one family, two subfamilies, four genera, and 17 species. Jordan and Evermann (1926) classified the billfishes into two families, four genera, and 32 species. Recently LaMonte and Marcy (1941) and Rosa (1950) classified the billfishes into four genera, 13 species and four subspecies, and four genera, 15 species and four subspecies, respectively, in their revisional works. Several authors have contributed substantially to the knowledge of the Indo-Pacific billfishes (e.g. Nakamura, 1938, 1949; Royce, 1957; Howard and Ueyanagi, 1965). Robins and de Sylva (1960, 1963) provided comprehensive discussions of the systematics of the Atlantic billfishes.

Nakamura, Iwai, and Matsubara (1968) classified the billfishes of the world into two families, four genera, and 11 species, using external and internal characters such as shapes of snout, fins, skull, vertebrae, viscera and nasal rosette, compression of body, position of anus, pattern of lateral line system, arrangement of scales, relative position of second dorsal and second anal fins, color and color patterns. The key given below is modified after that paper.

Key to Families, Genera and Species of Billfishes (See Figure 1 for illustration of key characters)

1a. No pelvic fin. A single caudal keel on side. Snout long and swordlike in shape and depressed in cross-sectional view. No scales on body. No teeth. Base of first dorsal fin short and well separated from base of second dorsal fin (Xiphiidae, Xiphias) ....Swordfish, *Xiphias gladius* Linneaus, Figure 1A

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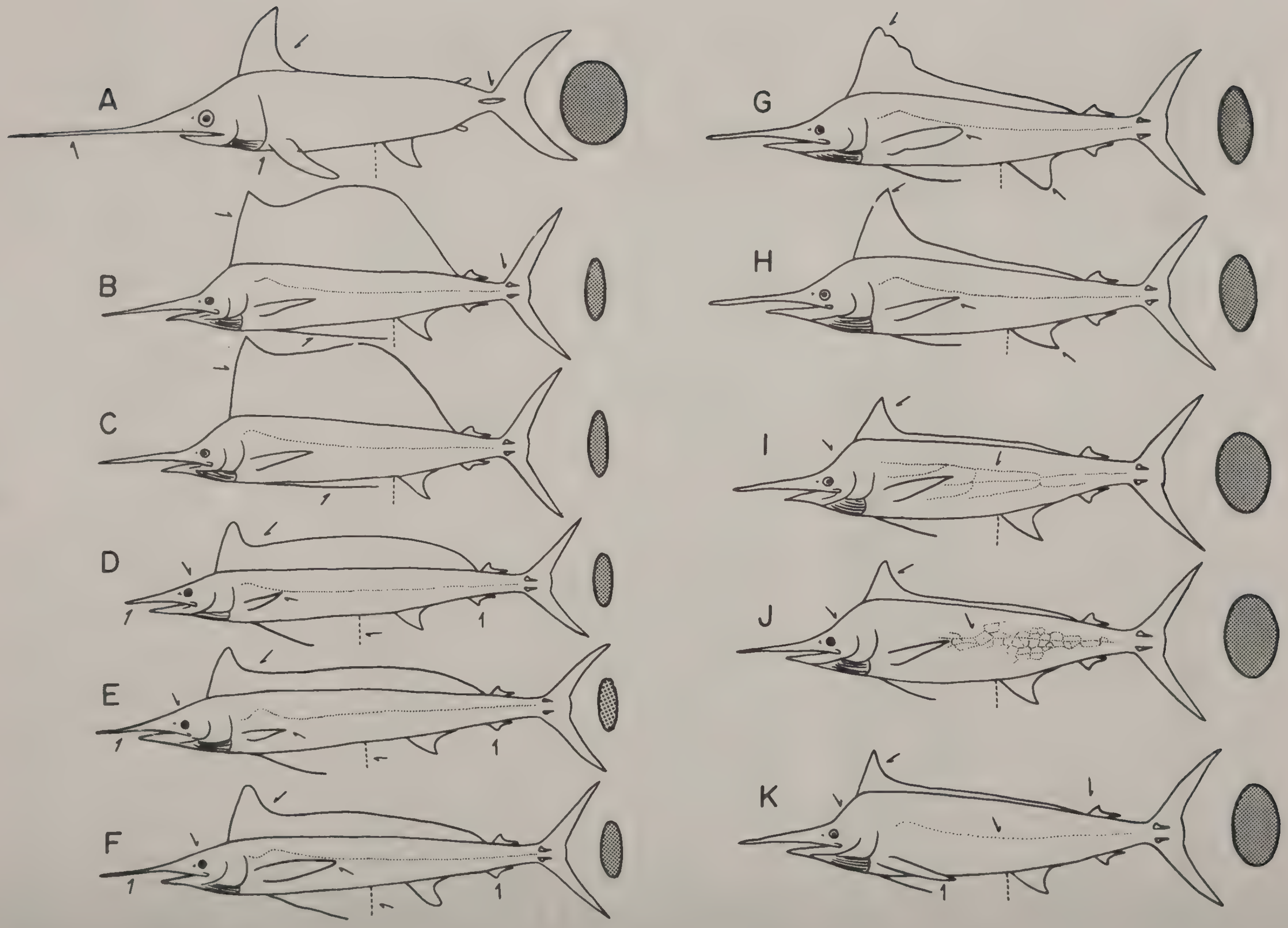

Figure 1.—External appearance of billfishes. Figures to the right of each species show cross-sectional views of sections taken at the base of pectoral fin. Arrows show the important points used in the key. **A.** *X. gladius* **B.** *I. platypterus* **C.** *I. albicans* **D.** *T. angustirostris* **E.** *T. belone* **F.** *T. pfluegeri* **G.** *T.*

1b.

Pelvic fin present. A pair of caudal keels on each side. Snout somewhat shorter and nearly rounded in cross-sectional view. Body covered with small elongated bony scales. Many small teeth. Base of first dorsal fin long and close to base of second dorsal fin (Istiophoridae), Figure 1, B-K 2

2a. First dorsal fin considerably higher than body depth at level of mid-body. Pelvic fin rays very long with well developed membrane *(Istiophorus)*, Figure 1B, 1C 3

2b. First dorsal fin only slightly higher to slightly lower than body depth at level of mid-body. Not sail-like in shape. Pelvic fin rays not as long, with moderately developed membrane, Figure 1, D-K 4

3a. Pectoral fin and caudal fin short in specimens of about 90 cm body length. Distributed in the Indo-Pacific Ocean ....
......................Indo-Pacific sailfish, *Istiophorus platypterus* (Shaw and Nodder), Figure 1B

3b. Pectoral fin and caudal fin long in specimens of about 90 cm body length. Distributed in the Atlantic Ocean ......Atlantic sailfish, *Istiophorus albicans* (Latreille), Figure 1C

4a. Height of anterior part of first dorsal fin slightly higher than or nearly equal to body depth. Body well compressed. External margin of head between preorbital and origin of first dorsal fin slightly elevated or not elevated *(Tetrapturus)*, Figure 1, D-H 5

4b. Height of anterior part of first dorsal fin lower than body depth. Body not well compressed. External margin of head between preorbital and origin of first dorsal fin highly elevated *(Makaira)*, Figure 1, I-K 9

5a. Anterior fin rays of first dorsal fin slightly higher than the remainder; latter nearly equal in height to end of the fin. Anus situated far in front of origin of first anal fin. Second anal fin situated somewhat before second dorsal fin, Figure 1, D-F 6

5b. Anterior rays of first dorsal fin somewhat higher than remainder of the fin; the height decreasing gradually posteriorly. Anus situated near origin of first anal fin. Second anal fin situated about under second dorsal fin, Figure 1, G-H 8

6a. Pectoral fin width less than 6.5 times pectoral fin length and 1.6-2.5 times head length 7

6b. Pectoral fin width more than 6.5 times pectoral fin length and 1.0-1.4 times head length ....Longbill spearfish, *Tetrapturus pfluegeri* Robins and de Sylva, Figure 1F

7a. Snout short; bill length about 1.6 times head length ....
.... Shortbill spearfish, *Tetrapturus angustirostris* Tanaka, Figure 1D

7b. Snout long; bill length about 1.2-1.5 times head length ....
............................Mediterranean spearfish, *Tetrapturus belone* Rafinesque, Figure 1E

8a. Pectoral fin wide, its tip rounded. Tips of first dorsal fin and first anal fin round ....White marlin, *Tetrapturus albidus* Poey, Figure 1G

8b. Pectoral fin narrow, its tip pointed. Tips of first dorsal fin and first anal fin pointed .... Striped marlin, *Tetrapturus audax* (Phillipi), Figure 1H

9a. Pectoral fin can be folded back against side of body 10

9b. Pectoral fin rigid cannot be folded back against side of body .... Black marlin, *Makaira indica* (Cuvier), Figure 1K

10a. Lateral line system with simple loops .... Indo-Pacific blue marlin, *Makaira mazara* Jordan and Snyder, Figure 1I

10b. Lateral line system reticulated .... Atlantic blue marlin, *Makaira nigricans* Lacépède, Figure 1J

CLASSIFICATION PROBLEMS WITH SOME SPECIES OF BILLFISHES

While re-examining the study of the world billfishes made by Nakamura, et al. (1968), C.L. Hubbs (personal communcation) has made me aware of the critical opinions expressed by some researchers about this work. Hubbs stated his views as follows: "Two of the main problems involve the name we should use for California species of *Istiophorus* and *Makaira*. I see that you have definitely listed separately *Istiophorus platypterus* and *I. albicans* and also *Makaira nigricans* and *M. mazara*. In recent correspondence with Dr. Robins I find that he feels that these two pairs of species, as you recognize them, are either identical or only subspecifically separable. In both cases he seems to find that the differences are rather definitely related to the fact that the species grow larger in the eastern Pacific than they do in the Atlantic. In the case of the two blue marlins, he says that he has found indications that the degree of network of the lateral line system and the differences in the osteology that have been used are both dependent on size of fish, but that probably does not explain all the differences."

In Nakamura, et al. (1968), both *I. platypterus* and *I. albicans* were recognized only tentatively as valid species; principally because data were lacking to establish with certainty whether the two forms were conspecific, subspecies, or distinct species. While data are still inadequate, I now feel that both forms can be recognized as subspecies. I consider that some distinctions noted between these two forms, especially in species of 90 cm, could be referable to subspecific status. These features include differences in maximum body length attained, relative length of pectoral fin (Fig. 2) and spread of caudal fin (Fig. 3). Morrow and Harbo (1969) reported that analysis of morphometric and meristic characters of sailfish from various localities in the Atlantic, Pacific, and Indian Oceans indicated that the genus is monotypic, composed of a single species that shows remarkably little variation in the characters examined. Further study of anatomical, ecological, behavioral, and other biological aspects is necessary to clarify the problems of speciation in sailfish. Until this is achieved, I retain the use of *I. platypterus* for the Indo-Pacific sailfish and *I. albicans* for the Atlantic sailfish.

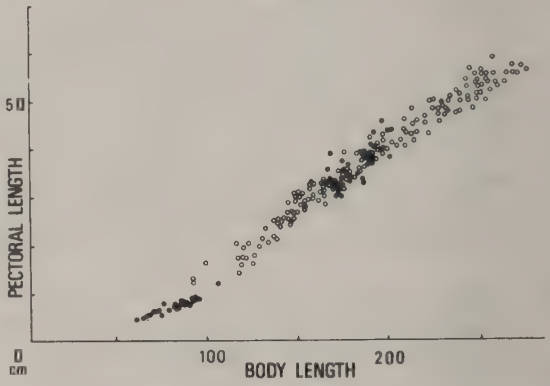

Figure 2.—Relationships between pectoral fin and body length in sailfish. Open circles show data from the Atlantic sailfish and solid circles show data from the Indo-Pacific sailfish. Data from Vick (1963) and Royce (1957) are included.

I believe that both *M. mazara* and *M. nigricans* are distinct species chiefly because of differences in the pattern of the lateral line system. In the specimens I examined, the differences were constant with growth (Fig. 4). It should be pointed out, however, that the lateral line systems of individuals larger than

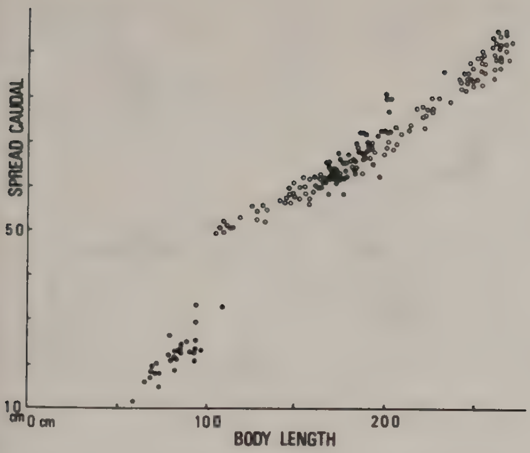

Figure 3.—Relationship between spread of caudal fin and body length in sailfish. Open circles show data from the Atlantic sailfish and solid circles show data from the Indo-Pacific sailfish. Data from Vick (1963) and Royce (1957) are included.

200 cm body length of both species are difficult to observe, because the lateral line system is covered under the thick skin and scales. For specimens less than 100 cm body length of both species, the characteristic patterns of the lateral line systems are easily recognized. In the Yaizu Fish Market, which is recognized as the world's largest landing market for tuna longliners, I observed and was able to separate many specimens of *M. mazara* and *M. nigricans* on the basis of different patterns in the lateral line system. With large specimens in which the lateral line was covered, I could not distinguish the species. I consider that the differences in the lateral line system are important enough to warrant recognition of both species.

Tetrapturus georgei Lowe was recognized by de Sylva (1972) as a valid species distributed in the western Mediterranean and off Spain and Morocco. Because of lack of specimens I have omitted consideration of *T. georgei* in this paper.

DISTRIBUTION OF BILLFISHES

The distribution of the billfishes discussed in the following sections is based primarily on unpublished data obtained from the Japanese longline catches made in the Pacific, Indian, and Atlantic Oceans. These data were made available by the Far Seas Fisheries Research Laboratory, Shimizu, Japan. The fishing grounds of the Japanese longliners extend from lat. 50°N to lat. 45°S in the Pacific Ocean, from the northern sectors of the Arabian Sea and Bay of Bengal to lat. 50°S in the Indian Ocean, and from lat. 50°N to lat. 50°S in the Atlantic Ocean.

Xiphias gladius

This species is distributed in the tropical and temperate waters of the Pacific, Indian, and Atlantic Oceans. Good commercial fishing grounds are located in the northwestern Pacific, off the Pacific coast of Mexico, off Ecuador, in the Arabian Sea, off Newfoundland, off southern Brazil, and the Gulf of

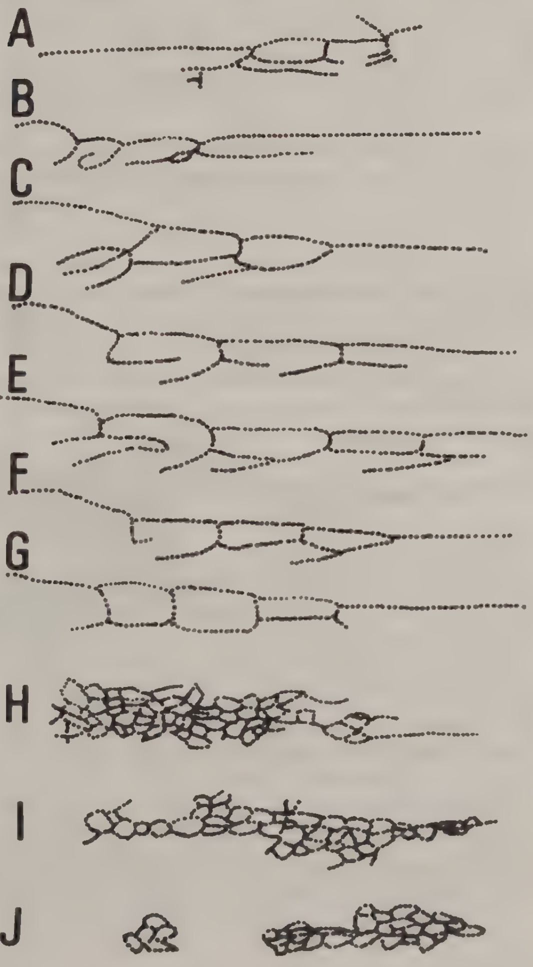

Figure 4.—Variations with growth of the lateral line systems of the Indo-Pacific blue marlin (A-G) and the Atlantic blue marlin (H-J). Body length: **A.** 17.7 cm, **B.** 81.0 cm, **C.** 84.3 cm, **D.** 112.9 cm, **E.** 119.5 cm, **F.** ca. 185 cm, **G.** ca. 260 cm, **H.** ca. 140 cm, **I.** 188.0 cm, **J.** ca. 205 cm.

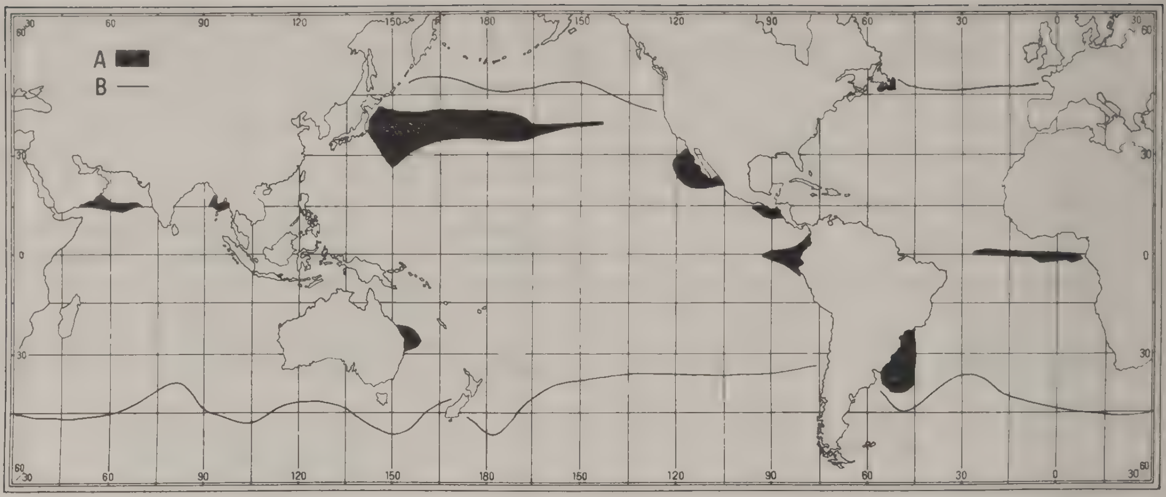

Figure 5.—Distribution of swordfish, *Xiphias gladius,* based on catch data from Japanese longline fishery during 1964-69. **A.** Good fishing grounds. **B.** Presumed northern and southern limits of swordfish.

Guinea (Fig. 5). Based on data of commercial catches, the limits of distribution appear to be about lat. 50°N to 35°S in the Pacific, lat. 45°S in the Indian Ocean, and lat. 45°N to 40°-45°S in the Atlantic (Fig. 5). This species is more abundant in coastal waters, but distribution is scattered and continuous in tropical open sea areas.

Istiophorus platypterus

This species is distributed in the tropical and temperate waters of the Pacific and Indian Oceans. Good commercial fishing grounds are located in waters of the eastern tropical Pacific from Baja California to Ecuador, the Coral Sea and around New Guinea, the East China Sea, the adjacent waters of southern India and Ceylon, and the Mozambique Channel (Fig. 6). The latitudinal limits of *I. platypterus* appear to extend from lat. 40°-45°N in the North Pacific and about lat. 40°S in the South Pacific, and in the Indian Ocean as far south as lat. 40°S. In the Japan Sea, sailfish migrate northward with the Tsushima Current during summer and migrate southward against the current during autumn.

Istiophorus albicans

This species is distributed in the tropical and temperate waters of the Atlantic Ocean. Good commercial fishing grounds are located in the Gulf of Mexico, the Gulf of Guiana, and the coastal waters off South America from Panama to Brazil (Fig. 6). The distributional limits are about lat. 40°N to lat. 35°-40°S in the Atlantic Ocean.

Tetrapturus angustirostris

This species is widely distributed in tropical and temperate offshore waters of the Indian and Pacific Oceans. Catches of this species are always low, except in the northwestern Pacific between lat. 15° and 30°N, where catches are relatively higher from about November through February (Nakamura, 1951; Royce, 1957; Ueyanagi, 1963). The distributional limits are about lat. 35°N to 35°S in the Pacific and Indian Oceans (Fig. 7).

Tetrapturus belone

This species is distributed in the Mediterranean and Adriatic Seas (Fig. 7) and is relatively rare. It occurs most commonly in the central Mediterranean (de Sylva, 1972). This species is not taken commercially.

Tetrapturus pfluegeri

This species is known with certainty only from the western North Atlantic where it occurs from southern New Jersey to Venezuela and from Texas to

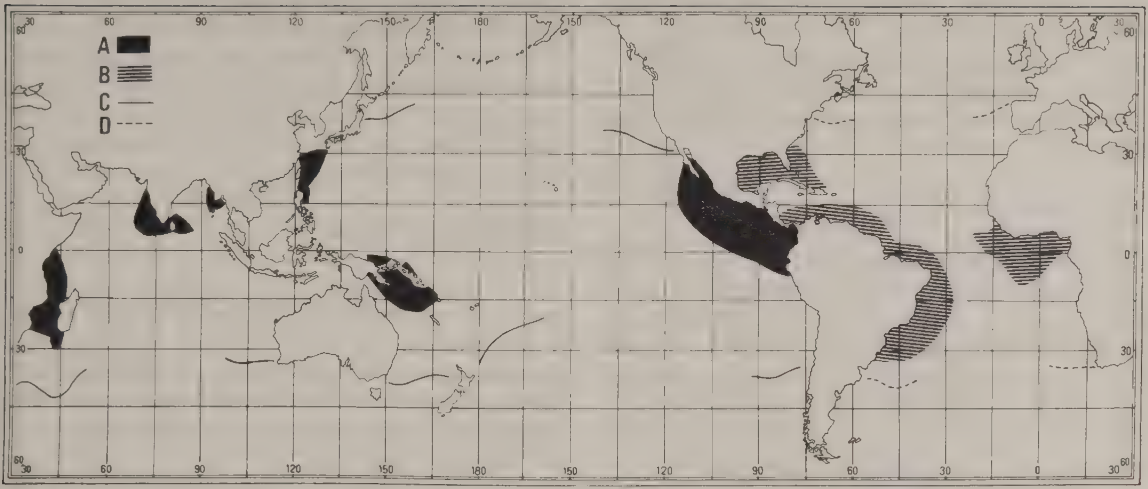

Figure 6.—Distribution of fishes of genus *Istiophorus* based on catch data from Japanese longline fishery during 1964-69. **A.** Good fishing grounds for the Indo-Pacific sailfish. **B.** Good fishing grounds for the Atlantic sailfish. **C.** Presumed northern and southern limits of the Indo-Pacific sailfish. **D.** Presumed northern and southern limits of the Atlantic sailfish.

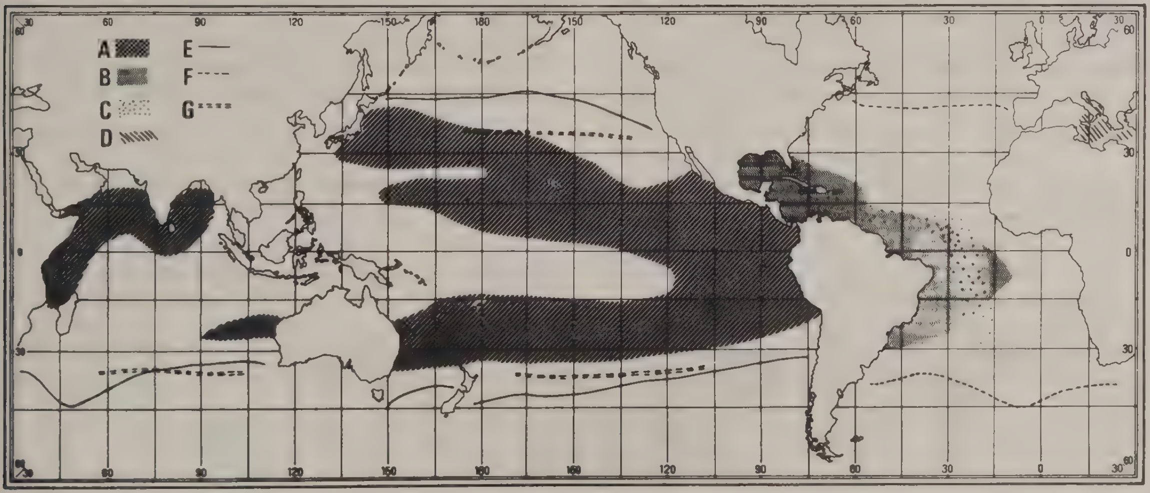

Figure 7.—Distribution of fishes of genus *Tetrapturus* based on catch data from Japanese longline fishery during 1964-69. **A.** Good fishing grounds for striped marlin, *T. audax*. **B.** Good fishing grounds for white marlin, *T. albidus*. **C.** Presumed distribution areas of the longbill spearfish, *T. pfluegeri*. **D.** Presumed distribution areas of the Mediterranean spearfish, *T. belone*. **E.** Presumed northern and southern limits of the striped marlin. **F.** Presumed northern and southern limits of the white marlin. **G.** Presumed northern and southern limits of the shortbill spearfish, *T. angustirostris*.

Puerto Rico (Robins and de Sylva, 1963). Longbill spearfish have been caught off the east coast of the United States and in the Central and South Atlantic Oceans (Fig. 7).

Tetrapturus albidus

This species is distributed in the tropical and temperate waters of the Atlantic. Good fishing grounds are located in the Gulf of Mexico, Carribean Sea, and the southwestern Atlantic (Fig. 7). The distributional limits are about lat. 45°N to lat. 40°S in the Atlantic Ocean. This species is caught in the Mediterranean Sea from Gibraltar to Italy (de Sylva, 1972).

Tetrapturus audax

This species is distributed in the tropical and temperate waters of the Indian and Pacific Oceans (Fig. 7). Based on catch data, the distributional pattern of this species in the Pacific is horseshoe-shaped with the base located along the central American coast. The latitudinal limits are about lat. 45°N to lat. 35°-40°S in the Pacific Ocean, as far south as lat. 45°S in the western South Indian Ocean and lat. 35°S in the eastern South Indian Ocean.

Makaira mazara

This species is distributed in the tropical and temperate waters of the Indian and Pacific Oceans. The Indo-Pacific blue marlin is the most tropical of the marlin species and it is primarily distributed in equatorial areas (Fig. 8). Good fishing grounds are located in the equatorial and tropical central Pacific Ocean, the South Pacific Ocean, and the equatorial Indian Ocean. The distributional limits are about lat. 45°N in the western North Pacific Ocean, lat. 35°N in the eastern North Pacific Ocean, lat. 35°S in the South Pacific Ocean, lat. 40°-45°S in the western South Indian Ocean and lat. 35°S in the eastern South Indian Ocean.

Makaira nigricans

This species is distributed in the tropical and temperate waters of the Atlantic Ocean and is the most tropical of the Atlantic billfishes. Good fishing grounds are located in the Gulf of Mexico, around the West Indies and off central Brazil (Fig. 8). The distributional limits are about lat. 40°N to lat. 40°S in the Atlantic Ocean.

Makaira indica

This species is distributed in the Indian and Pacific Oceans (Fig. 8). A few catches of this species have been recorded by fishermen from the Atlantic Ocean; however, the identifications have not been validated. It is conceivable that stray black marlin may invade the Atlantic Ocean by way of the Cape of Good Hope. In Figure 8, the dotted line shows the

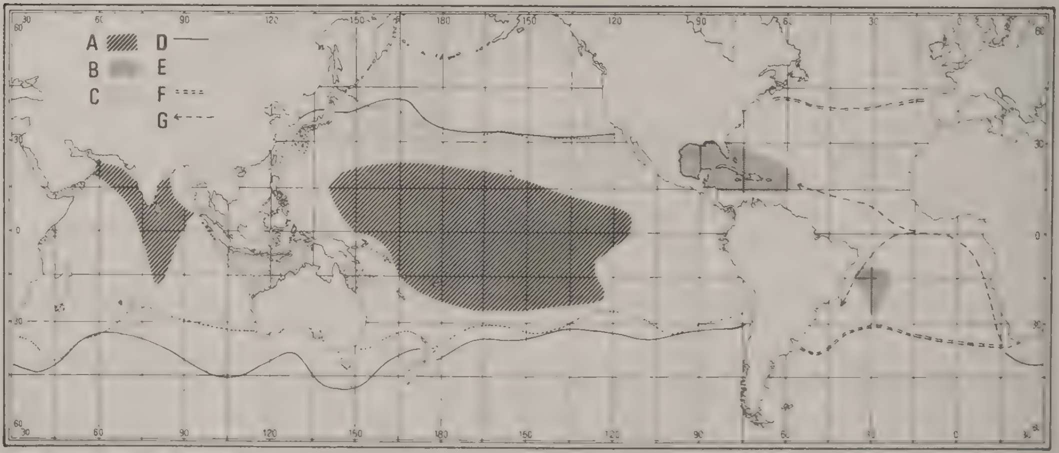

Figure 8.—Distribution of fishes of genus *Makaira* based on catch data from Japanese longline fishery during 1964-69. **A.** Good fishing grounds for the Indo-Pacific blue marlin, *M. mazara*. **B.** Good fishing grounds for the Atlantic blue marlin, *M. nigricans*. **C.** Good fishing grounds for the black marlin, *M. indica*. **D.** Presumed northern and southern limits of the black marlin. **E.** Presumed northern and southern limits of the Atlantic blue marlin. **G.** Presumed invasion of the black marlin from the Indian Ocean to the Atlantic Ocean.

presumed movement of black marlin from the Indian Ocean to the Atlantic Ocean. The black marlin, thus, is obviously a species of both tropical and temperate waters. Good fishing grounds are located in the East China Sea, Arafura Sea, Sulu Sea, Celebes Sea, Coral Sea, Formosa, northwestern Australia, Ecuador, and Pinas Bay in Panamá (Fig. 8). The distributional limits are about lat. 40°N in the North Pacific and lat. 45°S in the South Pacific and Indian Oceans.

ACKNOWLEDGMENTS

I wish to acknowledge Drs. Shoji Ueyanagi and Shoji Kikawa of Far Seas Fisheries Research Laboratory for their advice and for providing catch and effort data from the Japanese tuna longline fishery. I am also indebted to Susumu Kato of National Marine Fisheries Service, Tiburon Fisheries Laboratory, for his help and review of the manuscript.

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The Validity and Status of the Roundscale Spearfish, *Tetrapturus georgei*[1]

C. RICHARD ROBINS[2]

ABSTRACT

A fourth Atlantic species of the istiophorid genus *Tetrapturus* was discovered in 1961 among commercial catches landed in Sicily, Portugal, and Spain. Subsequent efforts to obtain information have failed because the fishermen do not distinguish the species and it is apparently much less common than *T. belone* in Sicily and *T. albidus* in Spain and Portugal.

The species is described in detail. Important distinguishing features are: the form of the scales on the midside, the shape of the lobes of the spinous dorsal and anal fins, the position of the anus, and the pectoral-fin length.

The nomenclatural validity of *Tetrapturus georgei* Lowe is discussed and reasons are given for applying this name to the newly discovered species.

In 1961 the author traveled to Sicily, Portugal, and Spain to study 95 specimens of istiophorid fishes that had been purchased and retained in commercial freezers for the purpose. Of 36 specimens examined in Sicily, 35 were Mediterranean spearfish, *Tetrapturus belone* Rafinesque, and these formed the basis for the redescription of the species by Robins and de Sylva (1963). Of the remaining 59 specimens, 56 were white marlin, *Tetrapturus albidus,* which formed the basis of reports by Rodriguez-Roda and Howard (1962) and Robins (1974). Four specimens represented an unknown species of *Tetrapturus,* whose presence had been unsuspected.

Based on a study of this material, Robins prepared and distributed a two page mimeographed leaflet requesting additional records and data. Inasmuch as the fishermen have never clearly distinguished the Mediterranean spearfish and the white marlin, it is not surprising that this additional spearfish should go undetected and no additional data have been forthcoming.

This report describes the species here called the roundscale spearfish, and the scientific name *Tetrapturus georgei* Lowe is applied to it in lieu of proposing a new name for it.

TETRAPTURUS GEORGEI LOWE

Roundscale spearfish

Nomenclature. Lowe (1840:36-37) did little more than announce his intention to describe a new species of *Tetrapturus* by which he would commemorate "by its specific name the valuable assistance rendered to the cause of ichthyology by Mr. George Butler Leacock." The only data are: 1) that the specimen was from Madeira; 2) that its pectoral fin was proportionally twice as long as in the description of *T. belone* by Valenciennes, in Cuvier and Valenciennes (1831), and that its body was "clothed with large scales of a peculiar shape and nature." No additional data were ever published, later accounts (Lowe, 1841:93; 1849:3) merely repeating the original. This was discussed by Robins and de Sylva (1960:397-398) who stated "The identity of *T. georgii* Lowe. . .will probably never be solved."

The discovery of an additional species from near Madeira requires reassessment of *T. georgei.* Beyond the three points of fact mentioned above, the matter becomes an exercise in logic. Even the matter of the scales involves interpretation.

Including the roundscale spearfish, as many as six species of Istiophoridae might occur in the vicinity of Madeira at least occasionally. According to Maul (in litt.), istiophorids are rare at Madeira and only appear during the summer. The white marlin, *T. albidus*, is likely the most abundant, as is supported by data in Ueyanagi et al. (1970) and Robins (1974). Moreover, a photograph sent by Maul in 1961 was identified by Robins as that of a white marlin. (This and other photographs were destroyed in a fire in 1967, but a surviving letter from Howard to Maul, 3 March 1961, discussed this photograph in detail.) This species has long pectoral fins in adults, 19-27 percent of body length for eastern Atlantic specimens vs. 10-13 percent of body length in adults of *T. belone* (Robins and de Sylva, 1963, Table 4), these data agreeing well with point two in Lowe's description. Valenciennes, in Cuvier and Valenciennes (1831), made no mention of scales in *T. belone* and thus there is no solid basis for judging Lowe's use of "peculiar." Compared to the naked *Xiphias* or to more typical fishes, the long needle-like scales of most istiophorids are indeed peculiar. *T. albidus* is unique in the family for the unblemished record of its specific name. It has always gone under Poey's name, although for many years it was referred to as *Makaira* and by some authors as *Lamontella* before Robins and de Sylva (1960) returned it to *Tetrapturus*. If it is judged that *T. georgei* is most likely the white marlin, the author would petition the International Commission of Zoological Nomenclature to reject the earlier name *T. Georgii* Lowe and preserve the well known junior name *T. albidus* Poey for this important game and food fish.

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The roundscale spearfish as noted below occurs in the eastern Atlantic, not far from Madeira, as well as in the Mediterranean. No doubt it reaches Madeira and many, if not all, of the eastern North Atlantic records of *T. pfluegeri* in Japanese literature (Ueyanagi et al., 1970) may be referable to it. Its pectoral-fin length varies from 20-26 percent of body length, also agreeing with Lowe's value. Its scales along the sides are rounded with posterior spikes, thus being less specialized than other istiophorid fishes. Whether these less modified scales are more "peculiar" depends on one's viewpoint. *T. georgei* easily could apply to this species which otherwise has no scientific name. In the interests of avoiding the need for a new name in a family with a cluttered nomenclatural history and in the interest of avoiding any possibility of applying *T. georgei* to *T. albidus* the author here restricts the name *T. georgei* to the roundscale spearfish.

Other species of Istiophoridae are judged to be less likely candidates. *T. pfluegeri* also has a long pectoral fin in adults (19-22 percent of body length) though not so long as in the two species already discussed. Further, its occurrence as far east as the Azores (Ueyanagi et al., 1970: Fig. 7) may in fact be based on the roundscale spearfish. The sailfish, *Istiophorus platypterus* Shaw and Nodder, has a short pectoral fin in the small-sized Atlantic fishes (14-19 percent of body length), and its remarkable dorsal fin surely would have elicited a comment from Lowe. The blue marlin *(Makaira nigricans)* is rare in the eastern North Atlantic but does occur at Madeira. G.E. Maul, in a letter (24 February 1961) to John K. Howard, refers to istiophorids in excess of 1,000 lb. These could be nothing else but blue marlin. This species has a fairly long pectoral fin (adults of Atlantic fish usually 18-24 percent of body length). The Mediterranean spearfish, *T. belone* Rafinesque, is not known to occur outside of the Mediterranean but may do so. It, of course, was the fish Lowe used as a basis of comparison and it has a short pectoral fin as already noted. Perhaps the most decisive statement that can be made of *T. georgei* is that it is not *T. belone*, and that authors like Albuquerque (1956), who treated it as a synonym of *T. belone* and thus extended the range of *T. belone* to Madeira, were in error.

Synonymy. *Tetrapturus Georgii* Lowe, 1840:36-37 (original description; type locality: Madeira) 1841:93; 1849:3 (original account repeated).

Tetrapturus georgii Robins and de Sylva, 1960:397-398 (name discussed, regarded as unidentifiable).

No other name has ever been applied to the species although the reference by Rodriguez-Roda and Howard (1962:495) to two unidentified specimens under study by Robins refers to this species.

The name is here modified to *Tetrapturus georgei* for reasons discussed by Bailey et al. (1970:5).

Taxonomy. The roundscale spearfish is referred to *Tetrapturus* Rafinesque (1810:51-55; type species *T. belone* by monotypy) as defined by Robins and de Sylva (1960:403-404 and in key).

Lowe's specimen of *T. georgeii* and his notes on it were apparently destroyed. Lowe perished in a shipwreck in the Bay of Biscay in 1874, and it is said that he had a large collection of Madeiran specimens and his manuscripts with him.

Diagnosis. Scales on sides of body round anteriorly usually with two or three posterior projections, the scales only slightly imbricate and soft. Scales dorsally and ventrally elongate imbricate and stiff, more typical of the Istiophoridae. Anterior lobe of spinous dorsal and anal fins rounded. Spinous dorsal fin high, unspotted. Nape moderately humped. Anus moderately far from anal-fin origin, the distance between them equal to about one-half the height of the first anal fin. Pectoral fin long in adults, subequal to pelvic fins, reaching beyond curve of lateral line. Isthmial groove present. Eye moderate about 2.9 percent of body length. Vertebrae: 12 precaudal plus 12 caudal. First dorsal-fin elements: 43-48.

Material examined. CRR-Med-1, male, fairly large but not in spawning condition, 1,600 mm body length, 21.5 kg, Sicily, near Messina, 2 August 1961 (specimen not retained). CRR-EAtl-1, female (no well developed ova), 1,570 mm body length, 20 kg, Portugal, trap off Faro, Cape Santa Maria, 27 May 1961 (piece of skin and pectoral girdle catalogued as UMML 11076). CRR-EAtl-2, female (no well developed ova), specimen broken, no measurements recorded, 23.5 kg, Portugal by longline off Cape Santa Maria, 9 August 1961. CRR-EAtl-3, female (no well developed ova), 1540 mm body length, 23.5 kg, Strait of Gibraltar, 5 October 1961.

Robins and de Sylva (1960:405-406) presented a key to the known species of Istiophoridae. At that time *T. pfluegeri* had not been distinguished from *T. belone* and the reference in the key to *T. belone* in fact refers to *T. pfluegeri*. Table 1 contrasts the four Atlantic species of *Tetrapturus*.

Taxonomic status. T. georgei is easily separable from other species in the genus by the characters given in the diagnosis and in Table 1. Although in some features it is intermediate between *belone* and *albidus,* it is extreme or unique in others so that it can not be a hybrid between them (see below). With so few specimens examined little can be said of variation and certainly nothing is known of its population structure.

Common names. Roundscale spearfish is proposed as the English common name for the species in recognition of its peculiar lateral scales. Lowe (1840) referred to it as peito. Albuquerque (1956) and others have used peto, but they have failed to distinguish istiophorid species, and peito or peto may be taken as comparable to the more general English word billfish rather than as a name for any one species.

Morphology. Morphometric data are presented in Table 2. Fin-ray counts are (in each instance the order of presentation is Med-1, EAtl 1, 2, 3): first dorsal 48, 45, 47, 43; second dorsal -, 7, 6, 6; first anal 16, 14, 15, 16; second anal -, 5, 7, 6; pectoral 19, 20, 20, 19. There were 12 caudal, 12 precaudal, and 24 total vertebrae in all four specimens.

The general body form of istiophorids changes with growth. Because all four specimens of *georgei* are of nearly the same size, the description below will apply only to adults. Juveniles and earlier life stages are unknown.

The dorsal profile is concave above the posterior part of the head, the nape being moderately humped. Exclusive of the sheath for the spinous dorsal fin, the dorsal and ventral profiles are nearly parallel. Behind this point the body narrows rapidly to the caudal peduncle. The general body form is best seen in Figure 1.

The body is fairly robust, being proportionally wider at the pectoral and first anal fin than *T. belone* and nearly equal to *T. albidus* in this regard.

The dorsal fin is moderately high posteriorly, its height at the 25th spine varying widely from 5.0-9.2 percent of total length. This is comparable to that of T. belone at the same size and higher than in *albidus*. The anterior lobe of the spinous dorsal fin is high (18-24 percent body length) and broadly rounded; likewise the first anal fin is high (12-15 percent body length) and broadly rounded. The dorsal fin is completely unspotted. This feature was checked especially on the sheathed portion of the fin where spots will persist even after severe treatment of sun drying, freezing, or preservative. In this regard *georgei* is similar to *pfluegeri, belone,* and *angustirostris*. None of the specimens exhibited bars on the body but these would have disappeared in the frozen specimens, so this condition is uncertain. However, neither *belone* nor *pfluegeri* is barred.

In istiophorids the pectoral fin usually is allometric in growth, sometimes, as in *pfluegeri* and *audax*, changing very rapidly from a short fin to long fin condition in a short size range. This fin is long in *georgei,* but the time or size of changeover is unknown. Presumably juveniles will have short pectoral fins.

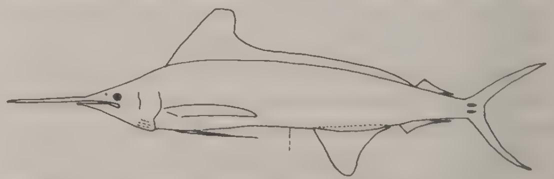

Figure 1.—Outline drawing of *Tetrapturus georgei* based on three photographs taken by Raimondo Sara of a specimen caught off Messina, Sicily, 1961, and with reference to measurements of other specimens (vertical dashed line indicates position of anus).

Table 1.—Comparison of four Atlantic species of *Tetrapturus* based on the most diagnostic characters.

Character	*Tetrapturus pfluegeri* Longbill spearfish	*Tetrapturus belone* Mediterranean spearfish	*Tetrapturus georgei* Roundscale spearfish	*Tetrapturus albidus* White marlin
Position of anus	Far anterior to anal-fin origin, the distance between them 8.4-11 percent body length and usually greater than height of first anal fin.	Far anterior to anal-fin origin, the distance between them 7.8-11 percent body length and equal to or exceeding height of first anal fin.	Moderately far anterior to anal-fin origin, the distance between them 4.8-7.6 percent body length and about half height of first anal fin	Close to anal-fin origin, the distance between them 3.3-5.2 percent body length and about one quarter the height of first anal fin
Lobes of first dorsal and anal fins	Pointed (the dorsal slightly rounded in large adults)	Pointed	Rounded	Rounded
Pattern of first dorsal fin	Unspotted	Unspotted	Unspotted	With numerous bluish black spots
Scales along midside in adults	Pointed, pungent	Pointed, pungent	Rounded with few large posterior points, soft	Pointed, pungent
Pectoral-fin length in adults	Long, subequal to pelvic fins, reaching beyond curve of lateral line	Short, even in adults, barely reaching curve of lateral line	Long, subequal to pelvic fins, reaching beyond curve of lateral line	Long, subequal to pelvic fins reaching beyond curve of lateral line
Orbit diameter (in percent of body length)	2.4-2.9	2.4-3.0	2.9	3.1-3.4
First dorsal fin elements	45-53 (usually 48-51)	39-46 (usually 42-45)	43-48	38-45 (usually 40-43)

Table 2.—Morphometric data for three specimens[1] of *Tetrapturus georgei* expressed in millimeters and in percentage of body length. Measurements are as defined by Rivas (1956) unless otherwise indicated. Numbers in parentheses refer to the numbered definitions of Rivas; see Robins and de Sylva, 1960:384-385 for explanation of abbreviations.

Specimen number	EAtl-3		EAtl-1		Med-1	
Body length(1)	1540		1570		1600	
First predorsal length (3)	360	23	346	22	360	22
Second predorsal length (4)	—	—	1,270	81	1,295	81
Prepectoral length (5)	412	27	393	25	390	24
Prepelvic length (6)	440	29	425	27	420	26
First preanal length (7)	915	59	950	60	940	59
Second preanal length (8)	1,235	80	1,242	79	1,280	80
Orig. D_1 to orig. P_1 (9)	212	14	170	11	172	10
Orig. D_1 to orig. P_2 (10)	270	18	232	15	235	15
Orig. D_2 to orig. A_2 (11)	153	9.9	145	9.2	147	9.2
Tip mandible to anus	856	56	825	52	830	52
Orig. P_2 to nape (13)	260	17	238	15	245	15
Greatest body depth (14)	275	18	231	15	240	15
Depth at orig. D_1 (15)	258	17	216	14	222	14
Depth at orig. A_1 (16)	220	14	205	13	210	13
Least depth cp (17)	66	4.3	54	3.4	60	3.8
Width at P_1 base (18)	115	7.5	96	6.1	110	6.9
Width at A_1 orig. (19)	125	8.1	113	7.2	122	7.6
Width at A_2 orig. (20)	92	6.0	90	5.7	91	5.7
Width cp (in front of keels)	54	3.5	45	2.9	40.5	2.5
Length upper keel (22)	58	3.8	41	2.6	53.5	3.3
Length lower keel (23)	53	3.4	51	3.2	49	3.1
Head length (24)	414	27	385	24	385	24
Snout length (25)	208	14	185	12	188	12
Bill length (26)	484	31	—	—	—	—
Maxillary length (28)	265	17	243	16	240	15
Orbit diameter (29)	45	2.9	46	2.9	46	2.9
Depth of bill (33)	15.4	1.00	12.8	0.82	—	—
Width of bill (34)	22.4	1.4	22.0	1.4	—	—
Height D_1 (39)	371	24	274	18	285	18
Length 25th D_1 spine (40)	141	9.2	78	5.0	92	5.8
Height D_2 (41)	67	4.4	69	4.4	61	3.8
Height A_1 (42)	236	15	190	12	210	13
Height A_2 (43)	51	3.3	—	—	48	3.0
Length P_1 (44)	405	26	—	—	330	21
Length P_2 (45)	328	21	—	—	344	22
Length last D_2 ray	107	6.9	105	6.7	—	—
Length last A_2 ray	92	6.0	97	6.2	82	5.1
Orig. D_1 to orig. D_2	910	59	936	60	930	58
Anus to orig. A_1	74	4.8	120	7.6	112	7.0
Weight (kg)		23.5		20		21.5

[1] The fourth specimen, EAtl-2, was damaged and no measurements were taken.

Flesh color is of uncertain value in istiophorid taxonomy but does reflect differences in myoglobin content. In *T. georgei* the flesh is distinctly redder than in *belone* and more like *T. albidus*.

Perhaps the most diagnostic feature of *georgei* is its lateral squamation. An area 100 × 100 mm is illustrated in Figure 2. Dorsal and ventral to this area, the scales are more elongate, stiffer, and with only one point or two closely approximated points. The lateral scales are softer and more flexible than in all other istiophorids. In counting vertebrae, the author makes a slit along one side to expose the centra. In running one's hand along this section, one always moves from front to back to avoid the very sharp posterior spine of istiophorid scales. The soft scales of *georgei* offer no such danger.

The lateral line is simple as in all species of *Tetrapturus*.

Relationships. T. georgei most resembles the white marlin, *T. albidus*. This is due largely to the somewhat humped nape and the broadly rounded anterior lobes of the first dorsal and anal fins.

Beyond that, however, comparison of the data in Table 2 with those presented by Robins (1974) for white marlin from the eastern Atlantic reveals differences only in four features: the width at the second anal fin (less in *georgei*), the orbit diameter (less in *georgei*), the length of the 25th dorsal spine, a measure of the posterior height of the fin (greater in *georgei*), and the distance from the anus to anal fin (greater in *georgei*).

The discovery of *georgei* makes more complete the transition between *Tetrapturus albidus* and *T. audax* on the one hand, called marlins because of their form and size, and the smaller species of spearfish, *T. belone*, *T. angustirostris*, and *T. pfluegeri*. Structurally, and in reference to the dendrogram in Robins and de Sylva (1960: Fig. 5), both *pfluegeri* and *georgei* would fall between *T. belone* and *T. albidus*. There is thus no clear division of the genus and no basis for recognizing as distinct subgenera *Tetrapturus* and *Kajikia*.

The continued placement of *albidus* in *Makaira* by Ovchinnikov (1970) is unexplained and naive. Likewise Ovchinnikov's distribution of *T. belone* is confused with *pfluegeri*, and his inclusion of *georgei* as a synonym of *belone* is incorrect.

Distribution. *Tetrapturus georgei* is positively known only from the specimens reported on here from Sicily, the Strait of Gibraltar, and the adjacent Atlantic Ocean off southern Portugal. Its occurrence at Madeira is inferred by application of the name *georgei*. Obviously this species can be expected to range widely in the eastern and perhaps central north Atlantic. Many of the records of *Tetrapturus pfluegeri* from these regions may be of *georgei*. Clarification of the central and eastern Atlantic records of spearfish from Japanese data (Ueyanagi et al., 1970) is of vital importance. The larvae and juveniles and their areas of occurrence are unknown. Data are too few to permit discussion of seasonal or annual variation in occurrence beyond the point that all istiophorids reaching Madeira and the southern coasts of Portugal and Spain do so during the warm months and that a movement south and west during the cold season may be assumed.

Hybridization. Hybrids in fishes are usually intermediate in characters most often used by systematists (i.e., fin-ray counts, body proportions) because these characters apparently are polygenic and the genes pleiotropic. This has been frequently discussed but perhaps nowhere more clearly than by Hubbs (1940:205-207; 1943). Whenever a rare species occurs which is intermediate in its characters between two more common species, there are a priori grounds for believing it to be based on hybrids between the two. Natural hybrids in fishes are most common among freshwater species where man's alteration of the environment has resulted in breakdown of ecological barriers. Hybrids are rarer among coastal fishes, rarer still in the stable environment of the tropical reefs, and unknown among truly oceanic fishes. Hybridization in a long established pelagic family like the Istiophoridae would seem to be highly unlikely.

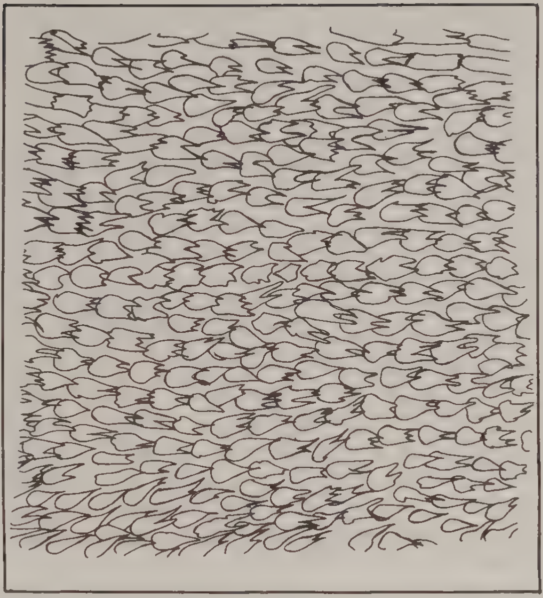

Figure 2.—Squamation of *Tetrapturus georgei*, patch 100 × 100 mm from right side below spinous dorsal fin. Drawing by Charles D. Getter.

Two possible hybrid combinations were considered in analyzing the characters of *georgei:* 1) *Tetrapturus albidus* × *T. belone*, and 2) *T. albidus* × *T. pfluegeri*. Analysis of Table 1 shows that *T. georgei* is intermediate in several of its most diagnostic characters between *T. albidus* and both *pfluegeri* and *belone*, namely the position of the anus and the diameter of its orbit. Its squamation is unique and the shape of its dorsal- and anal-fin lobes are as in *albidus*. Additional data for *pfluegeri* are available in Robins and de Sylva (1960, 1963) for *belone* in Robins and de Sylva (1963) and for *albidus* in Robins (1974). In the height of its first dorsal and anal fins, *georgei* is as extreme as *albidus*. In short, no good case can be made to consider *georgei* to be based on hybrids. Also, available evidence on spawning grounds of *belone* and *albidus* indicates that these species are at least 2,000 miles apart at spawning time. *T. albidus* and *T. pfluegeri* broadly overlap geographically, but whether *georgei* occurs in the western Atlantic is unclear.

Fishermen, particularly those working in the Gulf of Mexico, have described a fish they term a hatchet marlin in reference to the high and squarish anterior lobe of its dorsal fin. D.P. de Sylva has discussed this fish at this conference and has shown color slides provided by Robert Ewing of Monroe, Louisiana. I have also studied a series of black and white negatives of this fish. The shape of the first dorsal is dramatically like that in *georgei* (see Figure 1) and the scales appear large and rounded. However, the spinous dorsal and first anal fins appear much higher in the fish from the Gulf of Mexico. Certainly it appears that the hatchet marlin and the roundscale spearfish are closely related, if not identical, but no specimens of the former have ever been studied by scientists, and among contemporary biologists, only the writer has seen specimens of *georgei*. This species needs publicity in game-fish circles, with arrangements made to freeze specimens and bring them to the attention of appropriate scientists for study. This also calls attention to the growing need to provide contingency funds to preserve and ship such specimens, or to provide travel funds for scientists to the specimens when such rarities are caught by anglers.

Reproduction. All three of the known females were in a refractory state with no developed ova. They were collected 27 May, 9 August and 5 October. All were adults and this slim evidence may be taken to indicate that in *georgei*, like its Atlantic congeners, spawning is over by early summer. The only male, collected 2 August, still had fairly large testes but was not in spawning condition.

Nothing else is known of the bionomics and life history of the species.

An additional species of *Tetrapturus* is shown to exist in the northeastern part of the Atlantic Ocean and in the Mediterranean Sea. The name *Tetrapturus georgei* Lowe, previously regarded as unidentifiable, is applied to this species. The nomenclature is discussed in detail, and reasons for so restricting and applying this name are given.

The species is described on the basis of study of three females and one male, all adults. Morphometric data are available for three, one having been mutilated in a way that such data were unusable. *T. georgei* is contrasted with the other Atlantic species of *Tetrapturus: T. belone, T. pfluegeri,* and *T. albidus*.

The possibility that the specimens of *georgei* represent hybrids between other species is discussed and rejected.

Known information on distribution and reproduction are summarized.

ACKNOWLEDGMENTS

Many persons have aided the University of Miami's long-term program on billfishes, and the trip to southern Europe in particular involved much cooperation with local biologists, fishermen, and officials. Their names are documented in detail by Robins and de Sylva (1960, 1963). Special thanks are due the late John K. Howard for his persistent support of billfish research and to Raimondo Sara, Rui Monteiro, and Julio Rodriguez-Roda for their considerable help in Sicily, Portugal, and Spain respectively.

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Evaluation of Identification Methods For Young Billfishes[1]

WILLIAM J. RICHARDS[2]

ABSTRACT

Most of the papers published from 1831 to date which deal with the identification of young billfishes (Families Xiphiidae and Istiophoridae) are reviewed. The present knowledge of the identification of adults is compared with the identification of young and problem areas are defined. Suggestions are made to resolve the present problems encountered with the identification of the young stages (eggs, larvae, and juveniles). These suggestions include the need for detailed osteological descriptions of the young, the need for an increased effort to collect specimens, and the need to artificially rear specimens in the laboratory.

The purpose of this paper is to review the identification work that has been done on young billfishes over the years, to summarize the present methods used for identifying young billfishes, and to evaluate the identification methods.

Knowledge of the young stages of fishes is useful for determining spawning areas and times, and for estimation of sizes of adult spawning stocks. Prerequisite to this knowledge is the ability to identify the young stages of the species in question —from eggs through larvae to juveniles.

Currently, there are two methods available to us to make these identifications. Both methods require a complete series of specimens which will show all the different stages of development plus the individual variations which may be found in a particular species.

The first method is to artificially fertilize eggs, then rear the products in the laboratory. This technique provides an ideal series of specimens with the only limitations being anomalies resulting from rearing under artificial conditions, and the possibility that your material is influenced by a limited number of parents. Both limitations can be circumvented by comparing reared specimens with specimens caught in the wild. Wild caught eggs can be collected and brought into the laboratory and reared, thus avoiding the difficulties of catching ripe fish or by maturing gonads artificially. This method has been used successfully for very early stages of billfishes (Sanzo, 1922).

The second method is to collect a large series of specimens in the field over a wide enough size range so that one can work backwards from the adult, utilizing characters common to the adults, then to juveniles, larvae, and eggs. This approach requires that enough specimens be collected to develop sufficient series so that all the necessary characters will be available. The problems inherent in the rearing method are not relevant to this method, particularly when the material is from a wide geographic range, preferably the entire spawning range of the species. The prerequisite for the taxonomic approach is a firm knowledge of the adults. Unfortunately, some adult taxonomic problems still exist and the first section briefly summarizes these problems.

IDENTIFICATION STATUS OF ADULTS

Nakamura, Iwai, and Matsubara (1968) completed the most recent review of the billfishes of the world. They recognized 11 species in two families, Xiphiidae and Istiophoridae; the former monotypic, the latter with 10 species in three genera. These species, their English and Japanese names, and their distributions are:

Xiphias gladius Linnaeus, 1758. Swordfish, Mekajiki. Cosmopolitan.

Istiophorus platypterus (Shaw and Nodder, 1792). Pacific sailfish, Bashokajiki. Indo-Pacific Ocean.

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[2] NOAA, National Marine Fisheries Service, Southeast Fisheries Center, Miami Laboratory, Miami, FL 33149.

Istiophorus albicans (Latreille, 1804). Atlantic sailfish. Nishibashokajiki. Atlantic Ocean.

Tetrapturus angustirostris Tanaka, 1914. Shortbill spearfish, Furaikajiki. Indo-Pacific Ocean.

Tetrapturus belone Rafinesque, 1810. Mediterranean spearfish, Chichukaifurai. Mediterranean Sea.

Tetrapturus pfluegeri Robins and de Sylva, 1963. Longbill spearfish, Kuchinagafurai. Atlantic Ocean.

Tetrapturus albidus Poey, 1860. White marlin, Nishimakajiki. Atlantic Ocean.

Tetrapturus audax (Philippi, 1887). Striped marlin, Makajiki. Indo-Pacific Ocean.

Makaira mazara (Jordan and Snyder, 1901). Blue marlin, Kurokajiki. Indo-Pacific Ocean.

Makaira nigricans Lacépède, 1803. Atlantic blue marlin, Nishikurokajiki. Atlantic Ocean.

Makaira indica (Cuvier, 1831). Black marlin, Shirokajiki. Indo-Pacific Ocean, possibly Atlantic Ocean.

Several papers published prior to and after Nakamura et al. (1968) disagree with the opinions expressed. Morrow and Harbo (1969) state that there is only one worldwide species of *Istiophorus* and that their data (which they do not present) do not support the contention made by Nakamura et al. (1968) that small Atlantic specimens (less than 90 cm) can be separated from small Indo-Pacific specimens based on relative lengths of the pectoral fin. Two papers (Morrow, 1964; Robins and de Sylva, 1960) consider the blue marlin to be one species. Nakamura et al. (1968) state that their conclusion is tentative. Nakamura et al. (1968) also state that *T. audax* may represent two species, one in the North Pacific and one in the South Pacific. Another species of spearfish, the roundscale spearfish, *T. georgei* (Lowe, 1840), is now recognized in the eastern Atlantic by Robins (paper presented at this symposium). Another problem is that the presence of the black marlin in the Atlantic has not, as yet, been thoroughly documented. However, for purposes of identification of the young, some of the current taxonomic problems should make little difference.

HISTORICAL SUMMARY OF DESCRIPTIONS OF YOUNG BILLFISHES

Nineteenth Century

Cuvier (*in* Cuvier and Valenciennes, 1831) was the first to describe young stages of a billfish. He gave a brief description of a young swordfish and included a figure of a juvenile. He also described a young 108-mm sailfish as a new species, *Histiophorus pulchellus,* and included a fine illustration of the specimen. Morrow and Harbo (1969) place this species in the synonymy of *I. platypterus*. Rüppell (1835a) described an 18-inch juvenile sailfish from the Red Sea which he also described as new as *H. immaculatus*. Two précis of Rüppell's description appeared in the same year (1835b, 1835c), but only his 1835a paper included an illustration. Morrow and Harbo (1969) also placed this species in the synonymy of *I. platypterus,* although the name is misprinted as *H. immaculatis* in their paper. Günther (1873-74) described and figured three young billfish which were later figured and briefly described by him again in 1880. The three figures defy identification because of distortions, lack of detail, and apparent errors by the illustrator, particularly in fin shape and detail. In his 1880 paper there is a brief description of a young swordfish and crude drawing of it.

Lütken (1880) briefly describes young istiophorids varying in length from 5.5 to 21 mm and compares them with those described by Günther. He presents a figure of his smallest specimen (5.5 mm) and reproduces Günther's original plates. He also describes young swordfish specimens in his possession and reproduces the figure of *X. gladius* from Cuvier. Lütken made no attempt to assign the young istiophorids to any particular species. Goode (1883) reviews these earlier works, reproduces all of the figures thus far cited, and adds one note on the report of a young swordfish by Steindachner (a publication I have not seen). His paper also includes an English translation of Lütken's (1880) Danish text.

Twentieth Century

Lo Bianco (1903) reported on the capture of young *X. gladius* and later (1909) reported on the capture of two 10-mm istiophorids in February from the Mediterranean, southeast of Capri. Since *T. belone* is the only istiophorid known from the Mediterranean, they are presumed to be larvae of *T. belone*. Padoa (1956) reviews this evidence, illustrates one of the specimens, and further reviews Günther's and Lütken's work which includes reproductions of their figures.

Sanzo (1909, 1910, 1922, and 1930), in several papers on swordfish, described eggs; described eggs and larvae at hatching; reexamined eggs and larvae; reared larvae from eggs through the yolk sac stage; described a 13-mm specimen; and described a 6-mm specimen. Sella (1911) confirmed Sanzo's (1910) work. Regan (1909) pointed out the resemblance of a young *Xiphias* (200 mm in length) to the fossil species *Blochius longirostris*. Regan (1924) described and figured this 200-mm juvenile and noted that *Phaethonichthys tuberculatus* Nichols, 1923, is actually a young swordfish and placed it in the synonymy of *X. gladius*. Fowler (1928) also figured a young swordfish (ca. 225 mm) and like Regan (1924) noted that *P. tuberculatus* Nichols was a synonym of *X. gladius*. Therefore, by early in the century the young stages of swordfish were well described. Later accounts which include descriptions of young swordfish are Arata (1954); Yabe (1951); Yabe, Ueyanagi, Kikawa, and Watanabe (1959); Jones (1958); Nakamura et al. (1951); Gorbunova (1969); Tåning (1955); and Tibbo and Lauzier (1969).

Several authors have described a few specimens of istiophorids (presumed sailfish) prior to descriptions of complete series. These descriptions are by Uchida (1937); Nakamura (1932, 1940, 1942, 1949); La Monte and Marcy (1941); Baughman (1941); Beebe (1941); and Deraniyagala (1936, 1952). Complete series of larval through juvenile stages of sailfish were both published in 1953. One by Voss (1953) was based on Atlantic specimens, the other by Yabe (1953) was based on Pacific specimens. Following these two publications, several papers also described sailfish based on complete series or else give important data on young forms. These studies are by Ueyanagi and Watanabe (1962, 1964); Gehringer (1956, 1971); Jones (1959); Jones and Kumaran (1964); de Sylva (1963); Ueyanagi (1963b); Arnold (1955); Springer and Hoese (1958); Mito (1966, 1967); Sun' (1960); Laurs and Nishimoto (1970); and Strasburg (1970).

Most of the work on identification of young stages of istiophorids other than sailfish has been done by Japanese scientists, particularly Dr. Shoji Ueyanagi on Pacific species. Ueyanagi (1957) demonstrated that *Kajikia formosana* (Hirasaka and Nakamura) was actually the young of the striped marlin, *T. audax*. He (Ueyanagi, 1959) also described a complete series of striped marlin young ranging in length from 2.9 to 21.2 mm in standard length. Nakamura (1968) described the young juveniles of this species.

The larvae of shortbill spearfish, *T. angustirostris*, were described by Ueyanagi in two papers (1960b, 1962) followed by a description of a juvenile by Watanabe and Ueyanagi (1963).

A larva of the black marlin, *M. indica*, was first mentioned by Ueyanagi and Yabe (1959), then described by them in a subsequent paper (1960). Smaller larvae were reported later in that year by Ueyanagi (1960a).

Larvae of the Pacific blue marlin, *M. mazara*, were described by Ueyanagi and Yabe (1959). Atlantic blue marlin *(M. nigricans)* larvae were first described by Gehringer (1956), although he suggested that they were *T. belone*. Ueyanagi (1959) suggested that they were in fact *M. nigricans*. Juveniles of *M. nigricans* have been subsequently described by de Sylva (1958), Caldwell (1962), Eschmeyer and Bullis (1968), and Bartlett and Haedrich (1968). Ueyanagi (1957) described the juvenile stage of *M. mazara*.

The larvae of white marlin, *T. albidus*, have yet to be described, although Ueyanagi (1959) suspected that some of Gehringer's (1956) sailfish larvae may be the larvae of this species. De Sylva (1963) described a juvenile white marlin and a photograph of a 7½-inch juvenile has been published (Florida Board of Conservation, 1968). Ueyanagi, Kikawa, Uto, and Nishikawa (1970) plot the distribution of white marlin larvae, but do not describe their features.

Larvae of *T. pfluegeri* and *T. georgei* have not been described, although Robins and de Sylva (1963) described a large juvenile of the former species. Sparta (1953, 1961) has briefly described the eggs and young of *T. belone*.

A number of summary papers have been written which discuss the identification of young billfishes. These are La Monte (1955); Padoa (1956); Jones and Kumaran (1964); Ueyanagi and Watanabe (1962, 1964); Strasburg (1970); Howard and Ueyanagi (1965); Ueyanagi (1963a and b); and Ueyanagi (1964). The last includes an excellent account for identifying young Indo-Pacific species.

To summarize the published work to date on the identification of young billfishes, the following stages have been described: eggs, larvae, and juveniles of *X. gladius;* the larvae and juveniles of all the Indo-Pacific istiophorids with the exception of juvenile black marlin; larvae and juveniles of Atlantic sailfish; juveniles of Atlantic blue marlin; juveniles of the white marlin; a juvenile of the western Atlantic longbill spearfish; and the eggs and a few young specimens of the Mediterranean spearfish. Nothing has been published on the young of the roundscale spearfish.

IDENTIFICATION METHODS

There is no problem in separating young swordfish from istiophorids since the former lack the strong pterotic and preopercular spines which are so prominent in the latter in the early stages. In sizes over 20 mm, the young are very dissimilar in appearance. The identification problems lie within the istiophorids. Ueyanagi (1964) has summarized the present methods used to identify young stages of istiophorids from the Indo-Pacific Ocean. No papers have appeared as yet distinguishing all the species of the Atlantic from one another. One major problem with this group is that meristic characters are not particularly useful. The full complement of fin rays does not appear until the young are at least 20 mm in length and, as I have shown in Table 1, the counts exhibit little interspecific differences with overlap in range of nearly every character. Only the swordfish is separable on vertebral numbers (26 vertebrae compared with 24 for istiophorids). The genus *Makaira* has 11 precaudal and 13 caudal vertebrae, whereas *Istiophorus* and *Tetrapturus* have 12 precaudal and 12 caudal vertebrae. This character is difficult to use with specimens less than 20 mm in length. The only other meristic character (with the obvious exception of the pelvic rays, since they are lacking in swordfish) of any use is the number of first dorsal rays. This will separate some species from each other, but there is sufficient overlap so that the number of rays alone cannot be used. For example, a specimen with a count of 42 could not be *T. angustirostris* or *T. pfluegeri,* but it could be any of the others. Therefore, first dorsal counts are only useful to eliminate some species.

I have reproduced here Ueyanagi's methods for separating the Indo-Pacific species of istiophorids as follows (I have changed his names to conform with present practices):

> "It is not easy to identify the larvae of different istiophorid species, because of their close resemblance with each other and of marked difference from their respective adults, generally speaking, in their morphological characteristics. This is particularly true with those of very early stage before the snout develops its specific characteristics. However, the specific separation of the larvae is possible throughout their entire range mainly on the basis of their head profile.
>
> "Following are the criteria for identification:
>
> "(1) Larvae under 5 mm in length: The characters, as shown in Table [2], can be used for specific separation, although snout length does not provide a useful clue.
>
> "(2) Larvae between 5 and 10 mm in length: Besides the criteria given in Table [2], snout length and size of eyes can be used. [*M. mazara*] larvae are recognized by their short snout. The ratio of snout length to diameter of orbit is largest in [*I. platypterus*], smallest in [*M. mazara*], and is between in [*T. angustirostris*]. More precisely, the ratio tends to be > 1 in [*I. platypterus*], < 1 in [*M. mazara*], and = 1 in [*T. angustirostris*] in specimens 7-8 mm length.
>
> "(3) Larvae between 10 and 20 mm in length: They are grouped into two on the basis of their snout length; the long snout group with [*T. angustirostris*], [*I. platypterus*], and [*T. audax*], and the short snout group with [*M. mazara*] and [*M. indica*]. In the former, the snout length exceeds $^1/_5$ of their body length, while in the latter, it does not. For the specific separation of the former group, Table [2] applies; [*T. angustirostris*] is distinguishable by black chromatophores on branchiostegal membrane, while [*I. platypterus*] is separated from [*T. audax*] by the difference of their head profile: Unlike [*T. audax*] with a straight snout, [*I. platypterus*] has a beak-like snout. And because of this difference in the shape of the snout, they are separable by the difference

Table 1.—Meristic characters of adult billfishes based on data compiled from Nakamura et al. (1968) and Merrett (1971).

Species	First Dorsal Rays	Second Dorsal Rays	First Anal Rays	Second Anal Rays	Pectoral Rays	Pelvic Rays	Vertebrae		
							Pre-caudal	Caudal	Total
I. platypterus									
Atlantic	42-47	6-7	11-15	6-7	17-20	3	12	12	24
Pacific	42-48	6-7	12-15	6-7	17-20	3	12	12	24
T. belone	39-46	5-7	11-16	6-7	16-20	3	12	12	24
T. pfluegeri	44-50	6-7	13-17	6-7	17-21	3	12	12	24
T. albidus	38-46	5-6	12-17	5-6	18-21	3	12	12	24
T. audax	37-42	5-7	13-18	5-6	18-23	3	12	12	24
T. angustirostris	47-51	6-7	12-15	6-7	18-19	3	12	12	24
M. nigricans	41-43	6-7	13-15	6-7	18-21	3	11	13	24
M. mazara	40-44	6	12-15	6-7	21-23	3	11	13	24
M. indica	37-42	6-7	12-14	6-7	19-20	3	11	13	24
X. gladius	38-49	4-5	12-16	3-4	17-19	0	10-11	15-16	26

of the location of snout in terms of the center of eyes. In [*I. platypterus*], the center of eyes is above the tip of snout, while in [*T. audax*], they are on a nearly same level.

"Separation of [*M. indica*] from [*M. mazara*] can be made on the basis of the form of the pectoral fin.

"(4) Larvae over 20 mm in length: On top of the criteria of Table [2], the following characters, as listed in Table [3], can be applied."

Ueyanagi has assumed for the identification of Atlantic specimens that *M. nigricans* will resemble *M. mazara*, *T. pfluegeri* will resemble *T. angustirostris*, and *T. albidus* will resemble *T. audax*. In his 1959 paper he tentatively identified Gehringer's (1956) unidentified specimens as blue marlin and some of his sailfish specimens as white marlin because Gehringer's illustrations resembled Pacific blue marlin and striped marlin.

EVALUATION OF IDENTIFICATION METHODS

The basic problem with the identification methods used for these young fishes is that only one character is used and this character is poorly substantiated with other characters. For example, when examining Ueyanagi's tables of diagnostic characters for larvae less than 5 mm in length (Table 2), only one character separates each of the five species considered—spearfish has branchiostegal pigment, striped marlin has the tip of the snout and center of eye on the same plane, etc.; otherwise, they have the other characters in common. In larvae between 5 and 10 mm, relative snout length is used since sailfish have a relatively long snout, blue marlin a relatively short snout, and spearfish a snout of intermediate length. For larvae between 10 and 20 mm in length the snout length and snout shape are slightly more reliable. With larvae over 20

Table 2.—Summary of the prominent diagnostic characters of istiophorid larvae less than 5 mm in length modified from Ueyanagi (1964).

Species characters	*Tetrapturus angustirostris*	*Istiophorus platypterus*	*Tetrapturus audax*	*Makaira mazara*	*Makaira indica*
Profile of head	Tip of snout is lower in level than center of eye.	Same as *T. angustirostris*	Tip of snout and center of eye are on a nearly equal level.	Tip of snout is lower in level than center of eye.	Same as *M. mazara*
	Anterior edge of orbit does not project forward.	Same as *T. angustirostris*	Same as *T. angustirostris*	Anterior edge of orbit projects forward.	Anterior edge of orbit does not project forward.
Presence or absence of chromatophores on the branchiostegal membrane.	Present	Absent Chromatophores generally present on the peripheral zone of lower jaw membrane.	Absent	Absent	Absent
Pectoral fins	Fins extend along the lateral side of the body and can be readily folded against the side of the body.	Same as *T. angustirostris*	Same as *T. angustirostris*	Same as *T. angustirostris*	Fins stand out from the lateral side of the body at a right angle and cannot be folded against the body without breaking the joint.

mm in length, three more characters are useful —number of dorsal rays, shape of the dorsal fin, and the nature of the lateral line.

Another problem with some of these characters is that they are very difficult to use. The number of dorsal fin rays that I have compiled in Table 1 exhibits a greater range than those given by Ueyanagi (Table 3). Therefore, a young specimen with ray counts at the extreme of the range—for example, a spearfish with 47 dorsal rays—is within the range of the sailfish. This specimen could be further complicated by having its dorsal fin fixed in the retracted position. Such a specimen is difficult to evaluate because it is almost impossible to erect the dorsal fin to determine its shape. Measurements are very difficult to make, particularly on the very small specimens less than 8 mm in standard length and, more often than not, the bodies are bent and the opercles are expanded. This latter feature makes it very difficult to maintain the animal on its side for making measurements under a microscope. Even when opercles are flattened in their normal position, measurements are difficult because the observer has to carefully manipulate the specimen in order to maintain the two points of measurement on a plane parallel to the plane of the measuring device.

Determining whether or not the anterior edge of the orbit projects is very difficult to evaluate. I have trouble with this character when I am simultaneously comparing this feature on specimens which have it projected and those which do not. Invariably, there are specimens for which this decision cannot be made. I have this same trouble with the character of whether or not the tip of snout is above, below, or on the same plane as the eye. If the specimen is fixed with its mouth open the tip of the snout is invariably above the center of the eye. Attempts to close the mouth generally distort the specimen so that this character is unusable.

I am suspicious of the premise that Indo-Pacific cognate species will resemble those from the Atlantic. Both white marlin juveniles collected in the Atlantic have 4 or 5 prominent ocellus-like spots (bright orange in life) on the dorsal fin. Its cognate from the Pacific, the striped marlin, as illustrated by Nakamura (1968), has a solid black dorsal fin.

In order to evaluate these identification methods more fully, I examined 86 istiophorid young ranging in standard length from 2.8 mm to 20.8 mm. Six of these specimens were collected and identified by Ueyanagi—five were Pacific blue marlin and one was an Atlantic blue marlin. The remaining 80 were all collected in the vicinity of Miami or in the central Gulf of Mexico and the distribution of adults from these areas could reveal the presence of the young of four species—sailfish, blue marlin, white marlin, and longbill spearfish. Only 11 specimens were 12 mm or longer in standard length. For each specimen I made the following measurements: standard length (tip of snout to the end of the notochord or hypural plate), snout length (from the tip of the snout to the anterior edge of the orbit), tip of snout to center of eyeball, horizontal diameter of the eye, horizontal diameter of the orbit, head length, distance upper jaw extended beyond the lower jaw, and length of the pelvic fin. On a few specimens, the vertical diameter of the eye and orbit were taken, but I eliminated this measurement because on many specimens the upper jaw bones projected above the lower rim of the orbit and eye,

Table 3.—Diagnostic characters usable in distinguishing the istiophorid larvae more than 20 mm in standard length modified from Ueyanagi (1964).

Species characters	*Tetrapturus angustirostris*	*Istiophorus platypterus*	*Tetrapturus audax*	*Makaira mazara*	*Makaira indica*
Number of first dorsal fin rays	More than 48	43-47*	Less than 45	Less than 45	Less than 45
Shape of first dorsal fin	Anterior-high type	Poterior-high type	Anterior-high type	Anterior-high type	Anterior-high type(presumed)
Lateral line	Single	Single	Single	Complex-having branches	Not single (?) (obscure)**

*This range is estimated from a small number of specimens.
**Lateral line pattern not yet ascertained.

making the measurement difficult to make with any accuracy. Ueyanagi and Yabe (1959) used this measurement in their description of the blue marlin. From these measurements I calculated standard length minus snout length and trunk length (standard length less head length). No meristic data were taken because of the small size of the specimens. Other data collected included the position of the snout in relation to the center of the eye (whether the snout was above, equal, or below a plane passing along the body axis through the center of the eye), the position of the pterotic spine (whether it was nearly parallel to the body axis or whether is projected upward at a 45° angle). This character was suggested to me by Dr. Ueyanagi (pers. comm.) as a possible means for separating striped marlin (parallel to the body) from sailfish (projecting upward). The remaining data collected concerned the number and location of chromatophores on the lower jaw, gular membrane, and branchiostegal membrane. First, the extent of pigmentation along the ramus of the lower jaw was noted, particularly whether this pigment was confined to the tip of the lower jaws or whether it extended posteriorly along ⅓, ½, ¾, or ⅞ of the distance of the lower jaw. In instances where this pigment varied from left to right side, the greatest value was used. The number of pigment cells occurring on the gular area was counted. These cells were always on the midline and variations of none, one, two, three, or more than three, were observed. Cases of more than three cells appeared as a distinct row along the midline and were noted as a row. Number and location of pigment cells on the branchiostegal membrane were also noted. In all but one specimen having branchiostegal membrane pigment, one cell occurred anteriorly on the midline. The one unusual specimen had one cell slightly displaced to the left. These variations of pigment are shown in Figure 1.

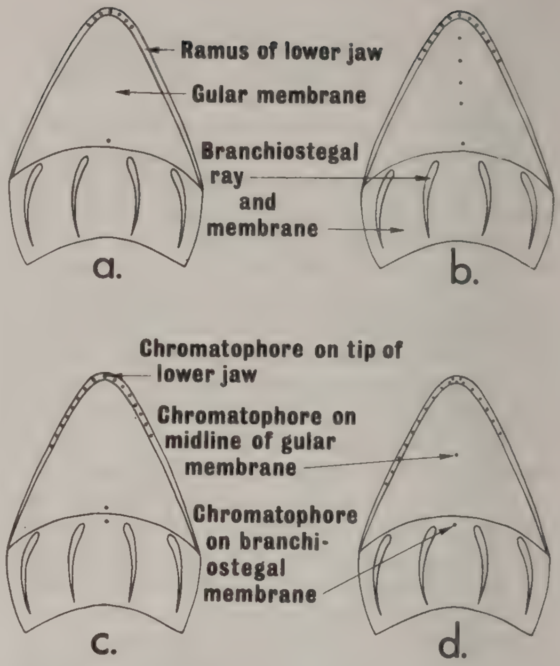
Ramus of lower jaw
Gular membrane
Branchiostegal ray and membrane
a.
b.
Chromatophore on tip of lower jaw
Chromatophore on midline of gular membrane
Chromatophore on branchiostegal membrane
c.
d.

Figure 1.—Diagramatic sketches of the pigment pattern on the lower jaw, gular and branchiostegal membrane of young istiophorids. **a.** Pigment pattern exhibits chromatophores concentrated on the tip of the lower jaw, one chromatophore on the posterior edge of the gular membrane midline, and no chromatophores on the branchiostegal membrane. **b.** Pigment pattern exhibits chromatophores extending along ½ the length of the left and right rami of the lower jaw, a row of cells on the midline of the gular membrane, and no chromatophores on the branchiostegal membrane. **c.** Pigment pattern exhibits chromatophores extending along ¾ the length of the lower jaw rami, one cell on the posterior edge of the gular membrane midline, and one cell on the midline of the branchiostegal membrane. **d.** Pigment pattern exhibits chromatophores extending along ⅞ of the length on the right rami and along ½ of the length of the left rami of the lower jaw, one cell on the midline of the gular membrane, and one cell on the branchiostegal membrane.

A rough analysis of the measurements produced generally negative results. The purpose of these analyses was to determine if more than one group was visible from inspection of plotted values. The only plots which did show differences were those involving the length of the snout. I show one such plot (Fig. 2) where the eye diameter divided by snout length and expressed in percent is plotted against standard length minus snout length. Specimens greater than 9 mm in standard length (greater than 7.5 mm in standard length minus snout length) showed separation into two groups. The 10 specimens with values greater than 75 percent included three blue marlin identified by Ueyanagi and seven specimens from my collections. These 10 have short snouts and I feel confident that they are blue marlin. In other plots which involved snout length, these 10 specimens were obviously different. I then examined the additional data from these 10 specimens to see if they shared any other character. Eight of the 10 lacked gular pigment; the other two (a 10-mm specimen provided by Ueyanagi and a 12.1-mm specimen from my Miami material) each had one

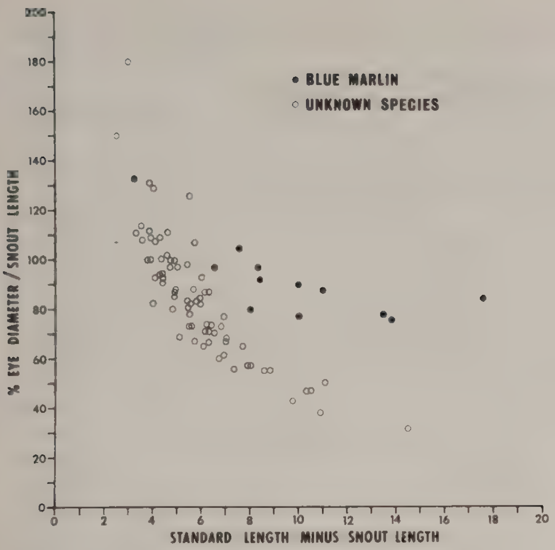

Figure 2.—Relation between eye diameter divided by snout length expressed in percent and standard length minus snout length in mm for istiophorid young. Blue marlin indicated by open circles, unknown species by closed circles.

chromatophore on the midline of the gular membrane. None of the 10 had any pigment on the branchiostegal membrane. Lower jaw pigment was confined to the tip or never extended back further than ⅓ the length of the ramus. Eight of the 10 specimens had the tip of the snout below a plane drawn along the body axis through the eye; two had the tip level with the eye (the 12.1-mm Miami specimen and a 9.9-mm specimen from the Gulf of Mexico). The nature of the pterotic spine was variable—five specimens had nearly level spines, two had their spines projecting sharply upwards, and three had their spines directed upwards at a slight angle. The anterior edge of the orbit projected anteriad but no more so than many of the long-snouted specimens.

The three blue marlin identified by Ueyanagi, which were smaller than 9 mm in standard length, are also shown in Figure 2. They are very similar to the other blue marlin specimens. They all lacked gular pigment, had pigment confined only to the tip of the lower jaw, lacked branchiostegal pigment, and had the tip of the snout below the level of the eye. Two of the specimens had sharply angled upward pterotic spines, while one had this spine slightly angled upward.

All of the remaining specimens were grouped according to their pigment patterns. These groups are:

Group 1—distinct row of pigment on gular membrane midline; no branchiostegal pigment.

Group 2—distinct row of pigment on gular membrane midline; branchiostegal pigment present.

Group 3—two or three pigment cells on branchiostegal membrane; no branchiostegal pigment.

Group 4—two or three pigment cells on gular membrane midline; branchiostegal pigment present.

Group 5—one pigment cell on gular membrane midline; no branchiostegal pigment.

Group 6—one pigment cell on gular membrane midline; branchiostegal pigment present.

Group 7—no pigment on gular membrane midline; no branchiostegal pigment present.

Group 8—no pigment on gular membrane midline; branchiostegal pigment present.

The numbers of specimens in each of these groups, their size range, and frequency occurrence of the other characters studied are shown in Table 4, along with the data on the 13 blue marlin specimens. As one can see, there does not seem to be any relation between any particular set of characters one may choose. Those five specimens shown in Figure 2 with eye/snout percentages greater than 120 percent (very short snout) occur in Groups 7 (1), 1 (2), 5 (1), and 6 (1). Categorizing the blue marlin specimens in a like manner, 11 would be included in Group 7 and 2 included in Group 5. If there is validity to these groups then two of these five small specimens could be considered to be blue marlin since they occur in Groups 5 and 7.

I have presented this evidence to illustrate the variability of the characters used to identify larvae. Table 4 demonstrates that one can choose any particular character and separate larvae into groups, but it is difficult to substantiate any particular character with other characters. Since my material comes from a relatively small area, I may not have young of all the species which occur here. But whatever is the case, it appears that there is a great deal of variation in the characters. Ueyanagi's studies have been based on Pacific material so, perhaps, the variability that I find is confined to Atlantic specimens.

CONCLUSIONS

It is evident that a great deal of work is necessary to resolve the identity of young istiophorids. Primarily, it is necessary to collect a great deal of material from different areas and at different times of the year. Information from gonad maturation studies of all the species would be helpful to predict where and

Table 4.—Frequency distribution of pigment patterns, snout and pterotic spine positions for istiophorid larvae.

			Gular Pigment				Branchiostegal pigment		Pigment on lower jaw ramus		Pterotic spine direction			Snout to eye		
Group or species	No.	Size range (mm SL)	Row	2-3 cells	1 cell	0 cell	Present	Absent	>½	<½	up	intermediate	level	below	level	above
1	9	3.3-20.2	9	0	0	0	0	9	9	0	0	3	6	7	0	2
2	2	5.9-11.5	2	0	0	0	2	0	2	0	0	2	0	2	0	0
3	6	4.7-10.0	0	6	0	0	0	6	2	4	0	3	3	5	1	0
4	4	4.5- 7.6	0	4	0	0	4	0	2	2	1	2	1	4	0	0
5	21	3.7-10.9	0	0	21	0	0	21	9	12	5	8	8	16	5	0
6	14	4.4-14.5	0	0	14	0	14	0	6	8	3	2	9	12	1	1
7	9	2.8- 9.3	0	0	0	9	0	9	2	7	2	2	5	7	2	0
8	8	5.3-11.3	0	0	0	8	8	0	3	5	3	2	3	5	2	1
Blue marlin	13	3.7-20.8	0	0	2	11	0	13	0	13	4	4	5	11	2	0

when young may be expected. Now that we have the ability to rear pelagic fishes from the egg, a concentrated effort directed at billfish would be a great step towards solving the problem. It is also necessary to study internal features of the young, particularly the osteology of the axial skeleton which has proved useful for identifying young tunas.

ACKNOWLEDGMENT

I want to express my deepest gratitude to my colleague and friend Shoji Ueyanagi, Far Seas Fisheries Research Laboratory, Shimizu, Japan, for his interest in my studies of these fishes. Ueyanagi suggested many of the various avenues of research which I followed in this study and I greatly appreciate all of his help and encouragement.

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On an Additional Diagnostic Character for the Identification of Billfish Larvae with Some Notes on the Variations in Pigmentation

SHOJI UEYANAGI[1]

ABSTRACT

The larvae of five species of billfishes (Istiophoridae) occurring in the Indian and Pacific Oceans —sailfish, *Istiophorus platypterus;* shortbill spearfish, *Tetrapturus angustirostris;* striped marlin, *T. audax;* blue marlin, *Makaira mazara;* and black marlin, *M. indica*—have now been identified. The identification of these larvae has depended on such characters as the shape of the pectoral fin, pigmentation of the branchiostegal membrane, pigmentation of the lower jaw membrane, and head profile.

Some problems in identification remain, however, as for example in the differentiation between very small larvae (under 7 mm) of striped marlin and blue marlin. Recent studies have resulted in additional diagnostic characters which differentiate between these two species, namely the differences in the pterotic and preopercular spines.

The larvae of sailfish generally have pigment on the posterior half of the lower jaw, and this pigmentation is recognized to be species specific. There exist, however, some larvae of this species which lack this characteristic pigmentation, and the occurrence of these larvae seems to vary geographically from the more typical sailfish larvae.

One of the problems related to the identification of billfish larvae concerns the identification of the larvae of striped marlin, *Tetrapturus audax*. The head profile ("the tip of the snout and the midpoint of the eye are on a nearly equal level") has been regarded as a diagnostic character for this species. However, unlike the pigmentation pattern, this character is rather difficult to use, and there is a possibility of error depending on the physical condition of the specimens examined. For example, sailfish, *Istiophorus platypterus,* larvae have been erroneously identified as striped marlin due to the occasional close resemblance in this particular character (Ueyanagi, 1959: Figs. 4 and 5; Ueyanagi, 1963). Furthermore, in very small specimens of striped marlin and blue marlin, *Makaira mazara,* where the snout has not yet lengthened, discrimination between the two species is very difficult.

Because of these problems in identification, further studies were conducted to locate additional diagnostic characters. As a result, it was found that the pterotic and preopercular spines are effective characters particularly in differentiating the larvae of striped marlin from those of the other species.

GENERAL DESCRIPTION OF THE PTEROTIC AND PREOPERCULAR SPINES

Spination on the head is a prominent characteristic of the larval stages of billfishes, and chief among the spines are the pterotic spine and the main preopercular spine (the latter is hereafter referred to simply as preopercular spine). Although there are some variations among species in the length of the spines, the development of the spines appears to progress uniformly in all species. For this reason, the following general description of the development of these spines is restricted to that of blue marlin.

The pterotic and preopercular spines are absent in larvae under 3 mm in total length. After about 3 mm, the spines appear. They lengthen rapidly with growth of the larvae and are markedly developed when the larvae are about 6-7 mm long. At this size, the preopercular spine reaches slightly posterior of the anus when pressed against the side of the body.

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After the larvae exceed about 8 mm, the pterotic spine becomes shorter relative to body length, and growth rate of the preopercular spine also decreases with growth of the larvae. At a length of 11-12 mm, these spines virtually stop growing and their lengths relative to body length begin decreasing.

DESCRIPTION OF THE PTEROTIC AND PREOPERCULAR SPINES BY SPECIES

The following is a brief description of the pterotic and preopercular spines in the larvae of the Indo-Pacific billfishes. Black marlin, *M. indica*, is omitted due to lack of sufficient numbers of specimens. All descriptions are of the lateral aspect of the larvae.

Blue marlin (Fig. 1)

The pterotic spine rises obliquely from its base. In specimens larger than 4 mm, the spine tip extends well beyond the dorsal profile of the larva. The preopercular spine is slightly concave downwards near its base but on the whole, it is very slightly concave upward. Viewing it from the side, it runs very nearly parallel to the ventral profile of the larva.

Sailfish (Fig. 2)

The pterotic spine rises obliquely from its base. The spine is relatively longer than in the larvae of other species, and its tip extends markedly beyond the dorsal profile. As in the blue marlin the preopercular spine extends parallel to the body axis of the larva but it is not as curved as in blue marlin.

Shortbill spearfish, *T. angustirostris* (Fig. 3)

Both the pterotic and preopercular spines are shaped very similarly to those in the blue marlin. The preopercular spine is, however, shorter than in blue marlin and is also inclined further downward. Furthermore, the secondary preopercular spines are quite well developed in this species.

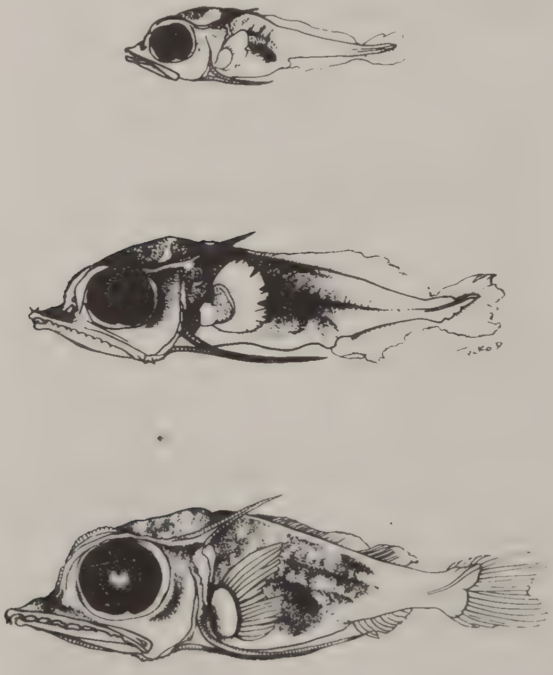

Figure 1.—Larvae of blue marlin, *Makaira mazara*. Top to bottom: 3.5, 6.0, and 7.6 mm in total length.

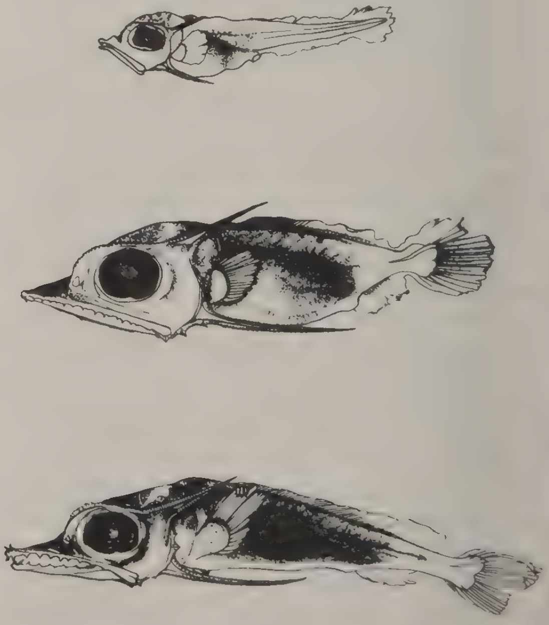

Figure 2.—Larvae of sailfish, *Istiophorus platypterus*. Top to bottom: 4.2, 6.5, and 8.3 mm in total length.

Striped marlin (Fig. 4)

In specimens under 4 mm in total length, the pterotic spine is inclined very slightly upward from the base, but with growth of the larvae, it runs very nearly parallel to the body axis. Thus the spine tip does not extend beyond the body profile as in other species. The preopercular spine is inclined sharply downward, forming a large angle with the body axis. The spine is nearly parallel to a line which might be drawn along the edges of the upper and lower jaws.

In order to facilitate comparison of the spines in the different species, schematic drawings of head profiles of the four species were prepared (Fig. 5).

USE OF THE SPINES AS DIAGNOSTIC CHARACTERS

The larvae of sailfish and shortbill spearfish can be identified reliably on the basis of pigmentation on the lower jaw or on the branchiostegal membrane and therefore identification of these species need not depend on supplementary characters such as spines. In the case of the blue marlin and striped marlin, however, supplementary diagnostic characters are essential in order that these species may be identified without error. The spine characteristics are particularly useful in differentiating the very small larvae, especially of blue and striped marlin smaller than 7 mm.

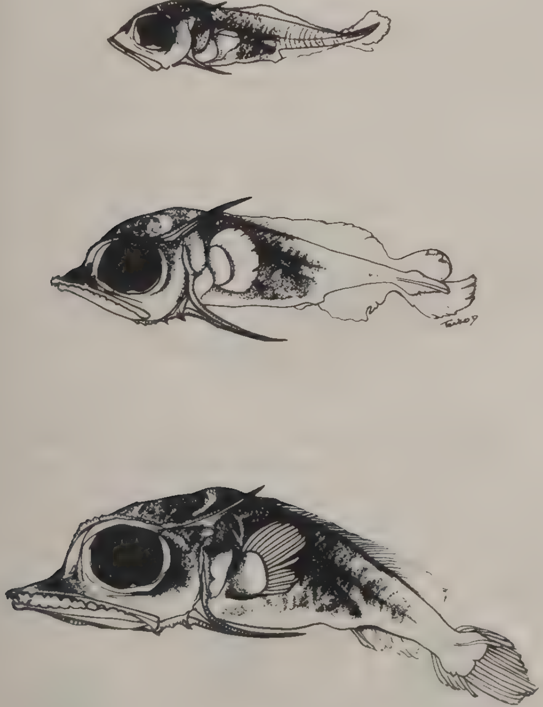

Figure 3.—Larvae of shortbill spearfish, *Tetrapturus angustirostris*. Top to bottom: 3.6, 5.5, and 8.6 mm in total length.

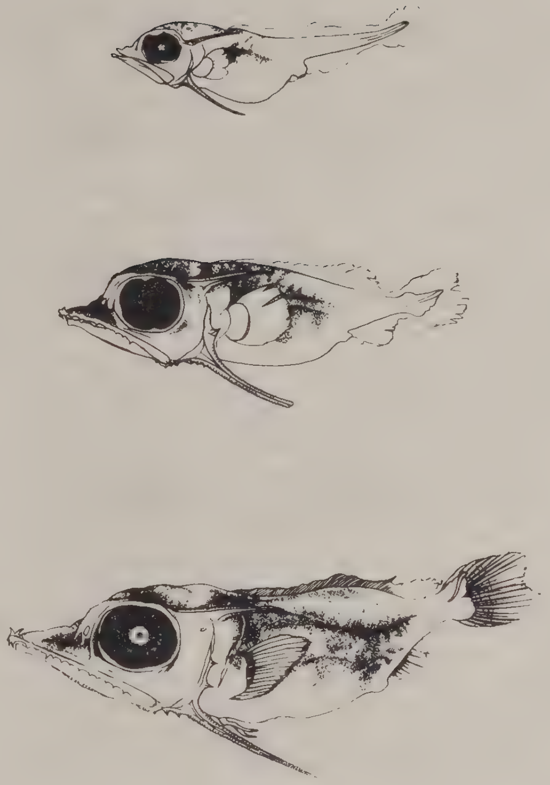

Figure 4.—Larvae of striped marlin, *Tetrapturus audax*. Top to bottom: 4.1, 5.6, and 8.9 mm in total length.

As mentioned previously, there are occasional specimens of sailfish larvae whose head profile very closely resemble that of striped marlin larvae. In these cases, also, the use of the supplementary characters will prevent errors in identification.

Although both the pterotic and preopercular spines tend to "degenerate" after the larvae attain a certain size, and thus become less useful as diagnostic characters, there are fortunately other characters which can be used effectively in the identification of larger specimens. The spines are thus useful and

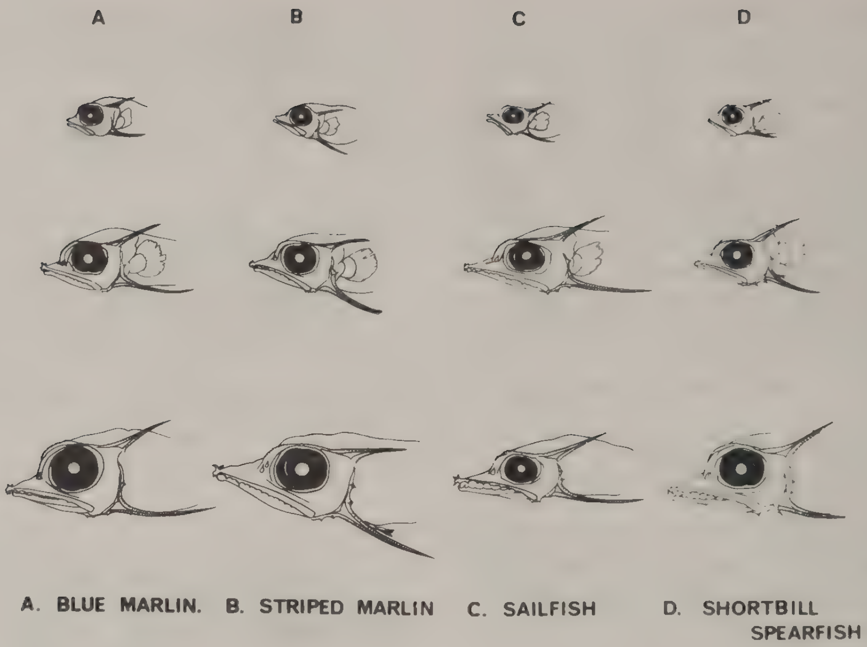

Figure 5.—Head profiles of larvae of four species of Indo-Pacific billfishes, with emphasis on the pterotic and preopercular spines. (Top row—about 4 mm; middle—about 6 mm; bottom—about 8 mm.)

effective diagnostic characters for larvae generally under 12-13 mm in total length.

The spines are occasionally found broken on specimens, but this should not deter their use since striped marlin can be reliably identified if there are at least one-half of the pterotic spine and one-third of the preopercular spine left for examination.

THE LARVAE OF ATLANTIC BILLFISHES

Although detailed studies were not possible due to the small numbers of larvae available from the Atlantic Ocean, it was, however, noted that the features of the pterotic and preopercular spines of the Atlantic species closely resembled those of the related Indo-Pacific species. Namely, the spines on the larvae of the Atlantic blue marlin, *M. nigricans* (Fig. 6), resembled those of the Indo-Pacific blue marlin; those of the Atlantic white marlin, *T. albidus* (Fig. 7), resembled those of the Indo-Pacific striped marlin; those of the Atlantic longbill spearfish, *T. pfluegeri* (Fig. 8), resembled those of the Indo-Pacific shortbill spearfish; and those of the Atlantic sailfish, *I. albicans* (Fig. 9), resembled those of the Indo-Pacific sailfish. Thus it appears that the differentiation between the larvae of the Atlantic blue marlin and white marlin can also be made on the basis of these spines.

VARIATIONS IN PIGMENTATION OF THE LOWER JAW OF SAILFISH

Based on five specimens, Ueyanagi (1963) presented a preliminary report on sailfish larvae which lacked the characteristic pigmentation on the posterior half of the lower jaw. Since then, additional studies have resulted in the examination of 37 such

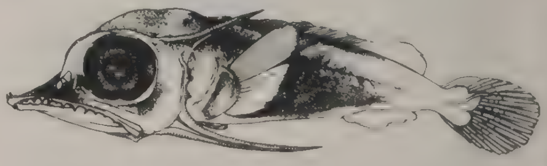

Figure 6.—Larva of the Atlantic blue marlin, *Makaira nigricans*, 9.0 mm in total length.

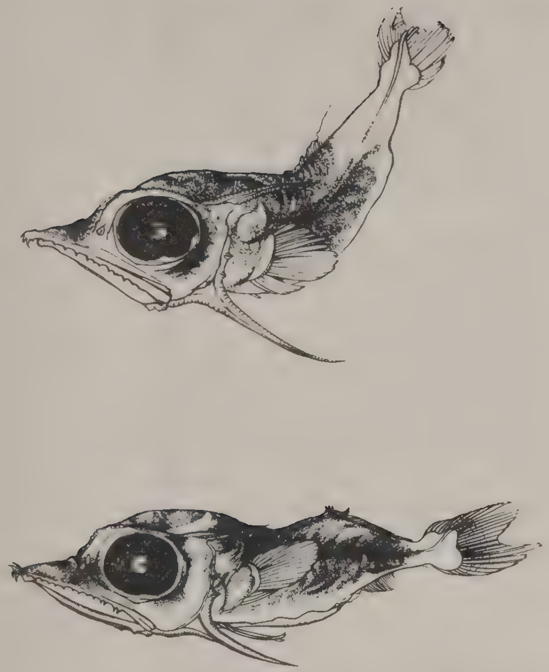

Figure 7.—Larvae of the Atlantic white marlin, *Tetrapturus albidus*. Upper, 6.5 mm; lower, 11.2 mm in total length.

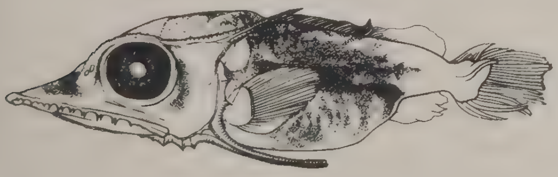

Figure 8.—Larva of the Atlantic longbill spearfish, *Tetrapturus pfluegeri*, 8.3 mm in total length.

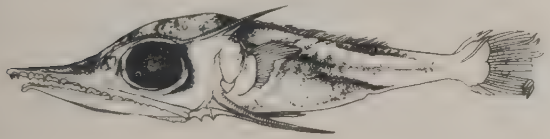

Figure 9.—Larva of the Atlantic sailfish, *Istiophorus albicans*, 11.8 mm in total length.

specimens from the Coral Sea and 23 from the waters northwest of Australia. The Coral Sea specimens measured between 2.5 and 29.5 mm while the latter group of specimens measured 4.0-37.6 mm in total length. All of the specimens lacked the characteristic pigmentation, but from head profile and body form characteristics, they were identified as larvae of sailfish.

The areas of capture of sailfish larvae, both those with and without pigmentation, were plotted by unit areas of 1° square (Fig. 10).

The larvae of sailfish are very sparsely distributed in offshore pelagic waters. Rather, they tend to be found most abundantly near land masses. This is seen to be true for both the pigmented and non-pigmented specimens. The non-pigmented larvae, however, seem to show an even greater affinity for land masses. Generally, both types of larvae were found in waters northwest of Australia (south of lat. 10°S), but in the Coral Sea the specimens were exclusively those which lacked pigmentation.

In regard to the occurrence of the non-pigmented sailfish larvae, Ueyanagi (1963) pointed out the possibility that these may represent a separate subpopulation or even be larvae of another species. Since from the taxonomic point of view it is very unlikely that they can be another species, I shall discuss some points here relating to the possibility that these are larvae of a separate subpopulation of sailfish. These points are:

1) It is unlikely that these are specimens in which the pigments had faded since there are as many as 60 such specimens available. While it does appear that the pigments on the lower jaw do fade out after the larvae reach about 60 mm in length, the specimens on hand are all under 40 mm in total length.

2) If these non-pigmented cases are due to individual variations, they would be expected to be distributed randomly throughout the distributional area rather than localized as in Figure 10.

3) It has been seen that pigmentation in the larval stages of closely related species is very similar. For example, the larvae of the Indo-Pacific shortbill spearfish and the Atlantic longbill spearfish both have pigmentation on the branchiostegal membrane. The Indo-Pacific sailfish and the Atlantic sailfish both have a pigmented lower jaw in their larval stages. These pigmentation patterns can therefore be considered to manifest close genetic relationships. The non-pigmented types are very probably variations of a genetic nature rather than those resulting temporarily from environmental influences.

Judging from the above-mentioned points, it appears that the non-pigmented larvae of the sailfish

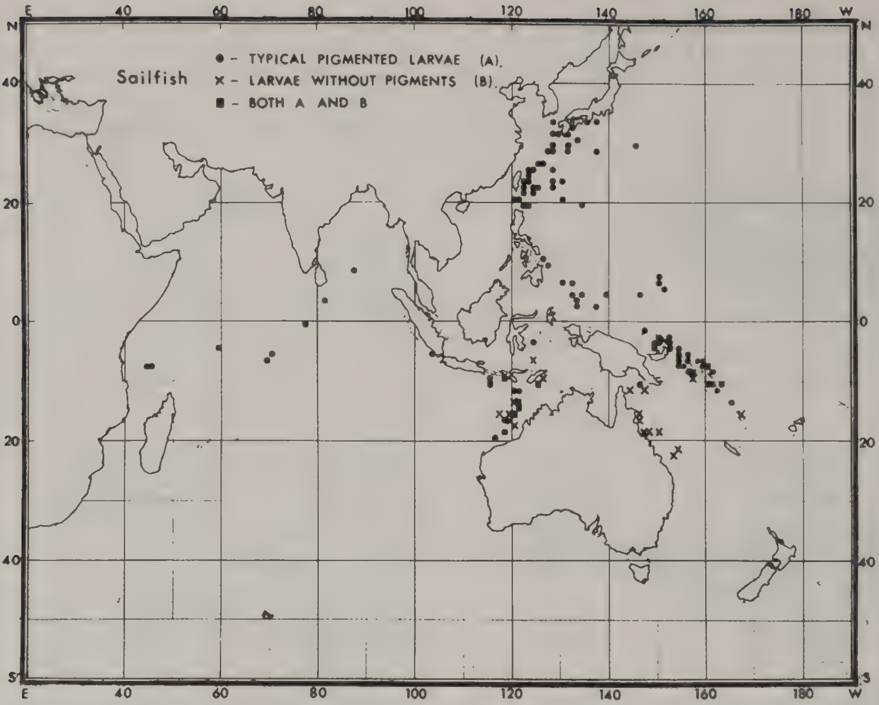
Sailfish
● - TYPICAL PIGMENTED LARVAE (A).
× - LARVAE WITHOUT PIGMENTS (B).
■ - BOTH A AND B
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Figure 10.—The occurrence of the two types of sailfish larvae (typical pigmented larvae and larvae without pigments) in the Indian and Pacific Oceans.

belong to a separate subpopulation from the pigmented larvae. To prove this point will require detailed studies on the ecology of the larvae as well as of the adults. If this hypothesis is correct, then studies of larval morphology will contribute not only to species identification, but also serve as a new approach towards population identification.

ACKNOWLEDGMENTS

I wish to sincerely thank Tamio Otsu of the National Marine Fisheries Service, Honolulu, who helped me with the English translation of the manuscript. Thanks are also due to Walter M. Matsumoto who read the manuscript. I am grateful to Teiko Doi who assisted in finding the diagnostic characters of the larvae and prepared the illustrations.

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Comparative Development of Atlantic and Mediterranean Billfishes (Istiophoridae)[1]

DONALD P. DE SYLVA[2] and SHOJI UEYANAGI[3]

ABSTRACT

Developmental stages from about 5 mm to the adult stage are described, illustrated, and compared for the following species: Atlantic sailfish, *Istiophorus platypterus;* white marlin, *Tetrapturus albidus;* Mediterranean spearfish, *Tetrapturus belone;* longbill spearfish, *Tetrapturus pfluegeri;* and Atlantic blue marlin, *Makaira nigricans.* Most descriptions are based on material from the western North Atlantic Ocean including the DANA collections from the Sargasso Sea. The status of two other billfish—*Tetrapturus georgei* from the eastern Atlantic and the so-called ''hatchet marlin'' of the western Atlantic—is discussed briefly in reference to the identity of an unidentifiable juvenile from the Mediterranean Sea.

[1] This paper was presented orally, but only title and abstract were submitted for publication. The full text of the paper will be submitted to the DANA Reports for publication.

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Life History of the Atlantic Blue Marlin, *Makaira nigricans*, with Special Reference to Jamaican Waters[1]

DONALD P. DE SYLVA[2]

ABSTRACT

Nomenclature and systematics of the Atlantic blue marlin are briefly reviewed. Its seasonal distribution in the Atlantic is analyzed from commercial and sport fish records. The spawning season in the North Atlantic, which occurs from late spring through late fall, is discussed. Larvae and juveniles are not common, but are easily identifiable. Spawning probably occurs far offshore, with the young developing in waters of the high seas. Feeding probably occurs in the deeper strata. Tunas, frigate mackerels, and cephalopods are the main food items. The growth rate has not been determined, but it is suspected that blue marlin exceed 15 years. Females attain a much larger size than the males; this is attributed to differential mortality. The blue marlin probably undergoes reasonably extensive migrations, and may be considered to comprise populations at least in the North Atlantic and South Atlantic Oceans. The sport fishery, which is extensive and expensive, and valuable economically, is thoroughly discussed. The commercial fishery for the species in the Atlantic is incidental to the tuna fisheries, yet there are some indications that the blue marlin is in some danger of being depleted through commercial activities.

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[1] This paper was presented orally, but only title and abstract were submitted for publication.

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On the Biology of Florida East Cost Atlantic Sailfish, *(Istiophorus platypterus)*[1]

JOHN W. JOLLEY, JR.[2]

ABSTRACT

The sailfish, *Istiophorus platypterus*, is one of the most important species in southeast Florida's marine sport fishery. Recently, the concern of Palm Beach anglers about apparent declines in numbers of sailfish caught annually prompted the Florida Department of Natural Resources Marine Research Laboratory to investigate the biological status of Florida's east coast sailfish populations.

Fresh specimens from local sport catches were examined monthly during May 1970 through September 1971. Monthly plankton and "night-light" collections of larval and juvenile stages were also obtained. Attempts are being made to estimate sailfish age using concentric rings in dorsal fin spines. If successful, growth rates will be determined for each sex and age of initial maturity described. Females were found to be consistently larger than males and more numerous during winter. A significant difference in length-weight relationship was also noted between sexes.

Fecundity estimates varied from 0.8 to 1.6 million "ripe" ova, indicating that previous estimates (2.5 to 4.7 million ova) were probably high. Larval istiophorids collected from April through October coincided with the prominence of "ripe" females in the sport catch. Microscopic examination of ovarian tissue and inspection of "ripe" ovaries suggest multiple spawning.

Florida's marine sport fishery has been valued as a $200 million business (de Sylva, 1969). Atlantic sailfish, *Istiophorus platypterus* (Shaw and Nodder), range throughout coastal waters and reside year-round in Florida where they are prominent among some 50 species of marine sport fishes. Sailfishing on Florida's east coast became popular during the 1920's and 1930's (Voss, 1953). Sailfish have been categorized as the most sought-after species by southeast coast marine charter boat anglers (Ellis, 1957). In addition, Ellis showed that sailfish were taken on 20% of the fishing trips sampled, but made up only 3 to 5% of the total numbers of fish caught. McClane (1965) estimated that more than 1,000 sailfish were caught each year between Stuart and Palm Beach; thus, this area became known as the "sailfish capital of the world."

The University of Miami Marine Laboratory (now Rosenstiel School of Marine and Atmospheric Sciences) initiated studies on the biology of sailfish in 1948 at the request of the Florida Board of Conservation (now Florida Department of Natural Resources [FDNR]). Voss (1953, 1956) described post-larval and juvenile stages and discussed the general biology of Florida's sailfish populations. De Sylva (1957) described age and growth from length frequencies from the sport catch (Petersen method), but suggested the results be checked by a more conventional method; specifically, annular marks. Further, de Sylva found a wide range in weight for a given length and age, suggesting the possibility of differential growth and/or mortality of sexes. Gross morphology and histology of gonads from Indian Ocean billfishes were described by Merrett (1970), but a thorough understanding of maturational cycles in Atlantic sailfish has yet to be obtained.

Florida's interest in the species was renewed in March 1970 by local concern for the welfare of the Palm Beach sailfishery. John Rybovich, Jr., representing local charter boat captains and anglers, examined catch statistics compiled by the West Palm Beach Fishing Club and Game Fish Research Association, Inc., and noted that the yearly catch of "gold button" sailfish (specimens eight feet or longer) had decreased significantly since 1947 (Fig. 1). Two gold button sailfish were reported in 1970, six in 1971, and three in 1972. In addition, total numbers of sailfish of all sizes declined during the famous Silver Sailfish Derby from 1948 to 1967 (Fig. 2).

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[1] Florida Department of Natural Resources Marine Research Laboratory Contribution No. 208.

[2] Florida Department of Natural Resources Marine Research Laboratory, 100 Eighth Avenue SE, St. Petersburg, FL 33701.

Palm Beach anglers presumed that these declines represented a reduction in numbers of locally available sailfish. However, verification of their conclusion relies upon careful examination of several contributing factors.

An objective examination into the apparent decline of total numbers of sailfish (Fig. 2) revealed that Silver Sailfish Derby tournament effort (boat-days) decreased concomitantly (except during 1953-57) and apparently has stabilized since 1967. Reasons for this decline are not known. Calculations of catch per unit of effort (Fig. 3) from three popular sailfishing tournaments held in the Palm Beaches (Silver Sailfish Derby, 1935 to 1971; International Women's Fishing Association, 1956 to 1966; and Masters Angling Tournament, 1963 to 1971) revealed fluctuating patterns of relative abundance, but did not suggest a continued decline. Combined mean catch per unit of effort for these tournaments was 1.31 sailfish/boat-day (approximately 0.16 to 0.22 sailfish per hour). These figures exceed those reported for sailfisheries in the Gulf of Mexico (Nakamura, 1971; Nakamura and Rivas, 1972) and those at Malinda, Kenya (Williams, 1970). Wise and Davis (1973) found that Japanese longline catches in the Atlantic during 1956 to 1968 showed a significant increase in sailfish and spearfish per 1,000 hooks fished. This apparently suggests that the magnitude of Atlantic sailfish stocks had not been affected adversely up to 1968.

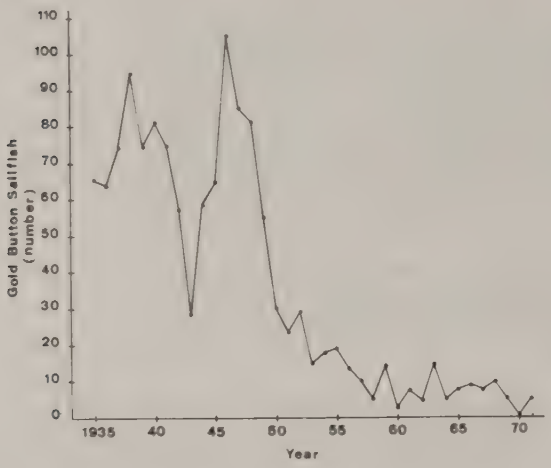

Figure 1.—Total number of "gold button" sailfish recorded by the West Palm Beach Fishing Club, 1935 to 1971.

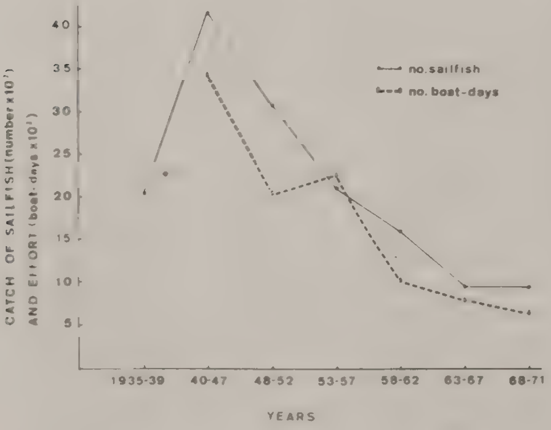

Figure 2.—Sailfish catch and effort data reported for five-year periods during the Silver Sailfish Derby, 1935 to 1971.

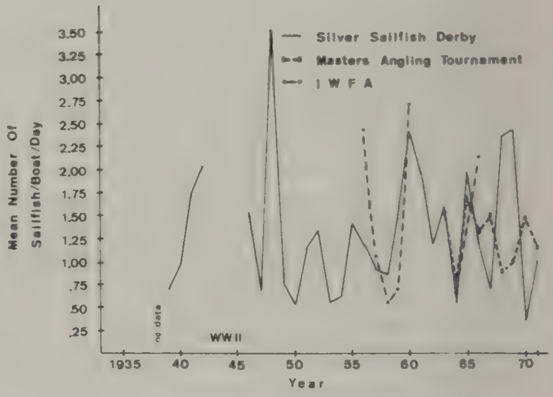

Figure 3.—Mean catch per unit of effort calculated from records of three popular sailfishing tournaments.

Obviously there is much contradictory information. Many knowledgeable anglers and boat captains insist that tournament catch per unit of effort has been maintained only by extending the fishing area northward in recent years and improving fishing methods. Thus the FDNR initiated studies designed to fully investigate the biological status of the species. Further assessment of the welfare of southeast Florida sailfish stocks may then be made.

METHODS AND MATERIALS

Sailfish taken by the sport fishery were examined from May 1970 through September 1971. Weekly visits to Pflueger Taxidermy in Hallandale and West Palm Beach, and Reese Taxidermy in Fort Lauderdale, facilitated examination of moderate numbers of specimens taken mainly from offshore Fort Pierce to Miami (Fig. 4). Occasionally, specimens from Georgia, Virginia, Bahamas, Florida Keys, and Destin, Florida were also examined.

Twenty-five to 35 fresh specimens were selected each month from a size range representative of the sport catch. Total, fork, standard, ''body'' (Rivas, 1956), and ''trunk'' (de Sylva, 1957) lengths were obtained to the nearest 0.5 cm with a 3 m measuring board. Total weight was taken to the nearest 0.2 kg, using a 68.0 kg capacity Chatillon (Model 100)[3] spring scale. Additional information was recorded concerning position of hook, bait used in capture, stomach contents, and presence of parasites

Two or three anterodorsal fin spines from each specimen were cleaned and placed in numbered envelopes. Spines were allowed to dry for several months before sectioning with a No. 409 emery disk (24.0 mm diameter × 0.5 mm thickness) mounted in a high speed Dremel Moto Tool (Model 270) with speed control (Model 219). This unit was mounted on an aluminum platform. A spring-loaded battery clamp was attached to a 180° rotating lever approximately 1 inch in front of the tool chuck. This securely held each spine during sectioning. Two or three cross sections were cut at 2.5 to 5.0 mm above the expanded base (condyle) of each spine (Fig. 5). Each section was then ground to approximately 0.75 mm with a No. 85422 grinding stone at low speed. Spinal sections were stored dry because water or glycerol causes excessive clearing. During examinations, however, spinal sections were temporarily immersed in glycerol and examined with a binocular dissecting microscope against a black background under reflected light. Circuli in each section have been counted once, but three additional independent readings will be made later by two biologists without reference to collection data.

Gonadal condition was evaluated macroscopically and a sample of tissue was removed for histological preparation. Gonadal tissue was initially preserved with Zenker's fixative. Tissue was rinsed with tap water and stored in Lugol's solution 18 to 36 h after collection. It was necessary to thoroughly leach out all fixative before final storage. At the St. Petersburg laboratory, gonadal tissue was imbedded in paraffin and sectioned at 6 μ . Slides were stained with Papanicolaou Haematoxylin (Harris) and Eosine Y, and with another stain developed by the

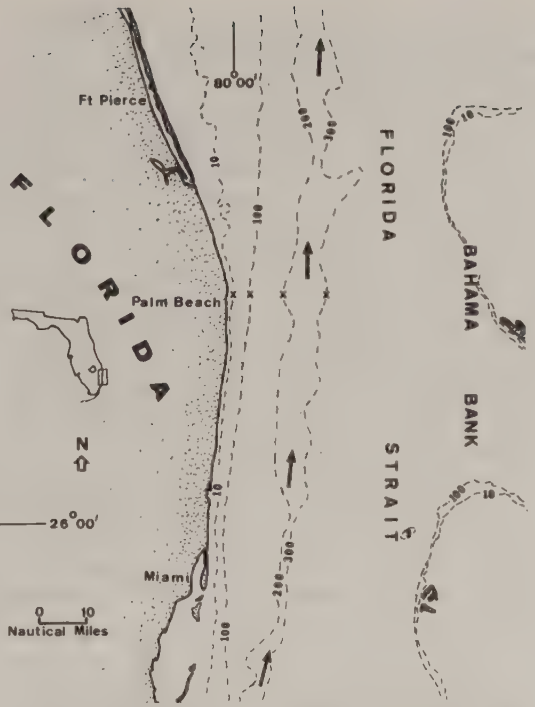

Figure 4.—Chart of southeast Florida showing area where most sailfish were obtained (almost the entire catch was taken between 10 and 100 fathoms). X's indicate station locations of monthly plankton and night-light collections. Aperiodic daylight collecting trips were conducted 5 to 15 nautical miles north and south of Palm Beach. Arrows indicate axis of Florida current; soundings in fathoms.

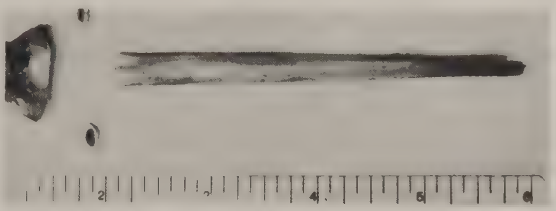

Figure 5.—Dorsal spine base, shaft and two sections after cutting.

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[3] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

histology laboratory. These slides are presently available for microscopic examination.

During the spawning season, whole "ripe" ovaries from fish weighing 15.9 to 38.0 kg (35.0 to 84.0 lb) were removed, weighed to the nearest 10 grams, and injected with 10% Formalin for fecundity estimates. These ovaries were usually "running ripe," i.e., large ova had ruptured from follicles and were flowing into the center of the lumen. Fecundity estimates were obtained by the subsampling by weight method described by Bagenal and Braum (1968) and Moe (1969). Techniques for determining distribution of mature ova within various sections of the ovary followed Otsu and Uchida (1959). Ova were successfully disassociated from ovarian tissue with microdissecting needle and forceps.

Monthly plankton and night-light collections were conducted from June 1970 through October 1971. Surface and oblique tows were made with 1 m plankton nets (mesh size 602 μ for body section and 295 μ for cod end). Supplemental daylight collecting trips were conducted aperiodically.

RESULTS AND DISCUSSION

Age and Growth

De Sylva (1957) reported that sailfish grow rapidly, attaining a weight of 9.1 kg (20 lb) within a year. Using the Petersen method, he estimated the average life span as 2-3 yr, but suggested that these results be checked by the more conventional assessment method of utilizing annular marks. Although Koto and Kodama (1962) indicated that circuli in scales, otoliths, centra, and fin rays of "Marlin" could not be recognized as annular, considerable effort is being expended to develop a technique to age individual sailfish. Sailfish pectoral and dorsal fin spines, branchiostegal rays, operculi, and vertebral centra were examined for growth marks; scales and statoliths were considered too small to be used. Two structures, vertebral centra and dorsal fin spines, showed distinct circuli which appeared to increase in number with fish length. However, each sailfish centrum is fused to part of the adjacent neural arch, and it is extremely difficult to remove the centra without damaging a specimen destined for trophy mounting. Therefore, dorsal fin spines III, IV, and V were selected as the aging structure since each of these spines has a relatively large base and is easily extracted. Spine removal poses no problem for the taxidermist because dorsal fins are not used in trophy preparation.

Increase in trunk length was compared with increase in width of the fourth (IV) spine for 132 specimens (Fig. 6). The linear equation, $y = 47.600 + 9.881x$, describes a line fitting the regression. An analysis of variance (Table 1) attests to the goodness of fit, thus satisfying the proportional growth requirement for use of a bony structure in aging (Parrish, 1958; Watson, 1967).

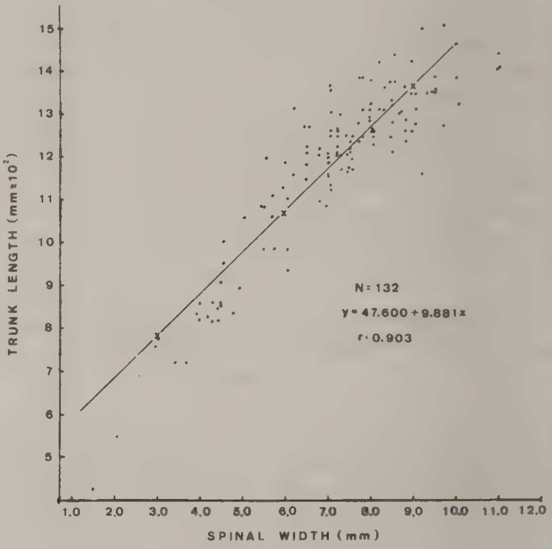

Figure 6.—Relationship of trunk length and fourth dorsal spine width. Spinal width was measured at 0.5 mm above the dorsalmost portion of each condyle.

Table 1.—ANOVA regression of trunk length on fourth spine width.

Source	*d.f.*	Sum of squares	Mean square	*F*
Spine width	1	42,426.8363	42,426.8363	[1]576.807
Residual	130	9,562.0936	73.5546	
Total	131	51,988.9299		

$y = 47.600 + 9.881\,x$

S^2b 0.169

% variation = 81.607

$r = 0.903$

[1] Sig. at $P = 0.05$.

Spinal sections from 193 specimens were read once. Initial results indicated that about 64 of the sections were clearly legible. These readings ranged from age groups 0 through VII (Table 2). Age group III was most numerous.

Narrow translucent (dark) and wider opaque (white) zones can be easily distinguished in a spinal section from one specimen (Fig. 7). The radius of the first circulus is greater than each successive radius. The central portion of all spines is vascular, and in large specimens this area often obscures the first and second circuli. Consequently, determination of the placement of these first circuli will depend upon careful examination of their positions in younger specimens.

Several additional methods have been tried to facilitate readings. A "burning technique" used by Christensen (1964) to emphasize annular marks on otoliths of the North Sea sole, *Solea solea,* was not effective on sailfish spinal sections. Staining with various concentrations of methylene blue was likewise ineffective. A magnified image produced by projection with a Bausch and Lomb overhead projector was not sufficiently clear to enumerate all circuli. Several spinal sections have been decalcified and stained with varying degrees of success. Some progress is now being made using these techniques.

Table 2.—Age readings of Atlantic sailfish using best sections from fourth dorsal fin spines.

No. circuli	0	I	II	III	IV	V	VI	VII
Frequency	3	4	15	21	12	5	2	2

N = 64/193

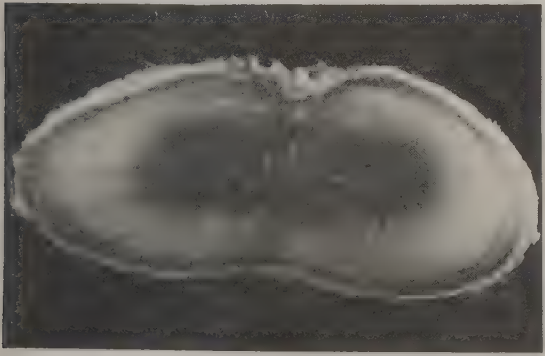

Figure 7.—Section from the fourth dorsal fin spine of a female in at least age group VI, wt=19.958kg, Dec. #10 - 1970.

Results thus far available from this study express the need for growth equations based upon accurate methods of aging. Females were found to be consistently larger than males (Table 3 and Fig. 8), and the sex ratio changed appreciably during the season; 65% of the sailfish examined from December through May were females (Fig. 9).

Nakamura and Rivas (1972) also noted that female sailfish from the Gulf of Mexico sport fishery were typically larger and more numerous than males. Considerable variation in sailfish weight at a given

Table 3.—Weight and trunk length of Atlantic sailfish examined May 1970 through September 1971.

Number individuals	Mean weight (kg)	Weight range (kg)	Trunk length range (cm)
Total = 412	17.0	0.5-39.5	
Males 182	14.9	2.3-27.4	70.0-144.0
Females 230	18.7	0.5-39.5	42.5-151.5
Total >18.1 kg = 177			
Males 50	20.6		
Females 127	23.6		

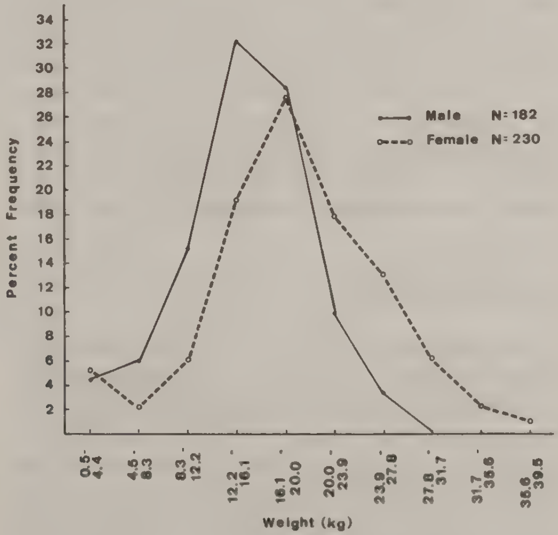

Figure 8.—Percent frequency distribution of 412 male and female sailfish by weight.

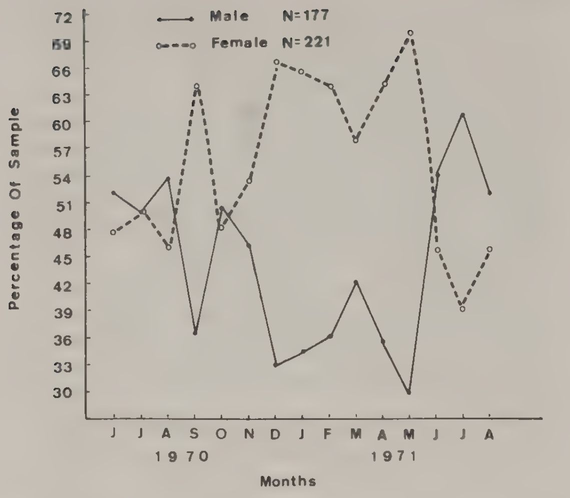

Figure 9.—Sex ratio of 398 sailfish expressed as a percent of each monthly sample.

age has been observed by de Sylva (1957) and Williams (1970), but no specific correlations have yet been made with regard to sex. Perhaps a difference in growth rate would account for the size disparity between sexes.

A significant difference was observed between the length-weight relationships by sex (*t*.05=3.121, *d.f.* 410). Females smaller than 137 cm trunk length were notably heavier than males of comparable length (Fig. 10). Merrett (1968:165) found no sexual distinction in the length-weight relationship of 120 Indian Ocean sailfish 126-194 cm "eye to fork length" (11.3 to 47.6 kg). Many of the fish he examined were considerably larger than those I weighed and measured (see Table 3). However, Williams (1970) acknowledged that a sexual difference in the length-weight relationship may exist, as is the case in marlins.

Reproduction

Gonadal tissues have not yet been fully evaluated microscopically. However, in assessing reproductive development from slides of Indian Ocean billfish gonadal tissue, Merrett (1970) reported that ovulation was probably not an all-or-none process, and that many resting oocytes were "reabsorbed." Similarly, Moe (1969) found that not all developing oocytes reached maturity in red grouper, *Epinephelus morio*. Many "rejuvenilized" during a resting stage subsequent to the spawning period. Beaumariage (in press) noticed a similar condition in young king mackerel, *Scomberomorus cavalla*. Such developmental characteristics will be considered when sailfish slides are examined.

Fecundity was estimated for eight sailfish varying in size from 17.2 to 27.4 kg (38.0 to 62.5 lb) (Table 4). Counts of "ripe" oocytes yielded fecundity estimates varying from 0.8 to 1.6 million ova. These oocytes constituted fewer than half the total number in the ovary. Voss (1953) estimated total fecundity of sailfish to be 2.3 to 4.7 million ova, probably an exceedingly high number of "ripe" oocytes. His counts were made from an ovary only 4.2% of specimen weight (Voss, 1953:227). Although he gave no size range for oocytes counted, I suspect they were not fully developed. I counted only the largest ova, 1.2 to 1.4 mm in diameter, from ovaries 8.1 to 12.7% ($\bar{x}$ = 9.9%) of specimen weight.

Correlation of gonadal tissue evaluations, larval sailfish abundance, and age estimates will allow definition of spawning frequency and age at maturity.

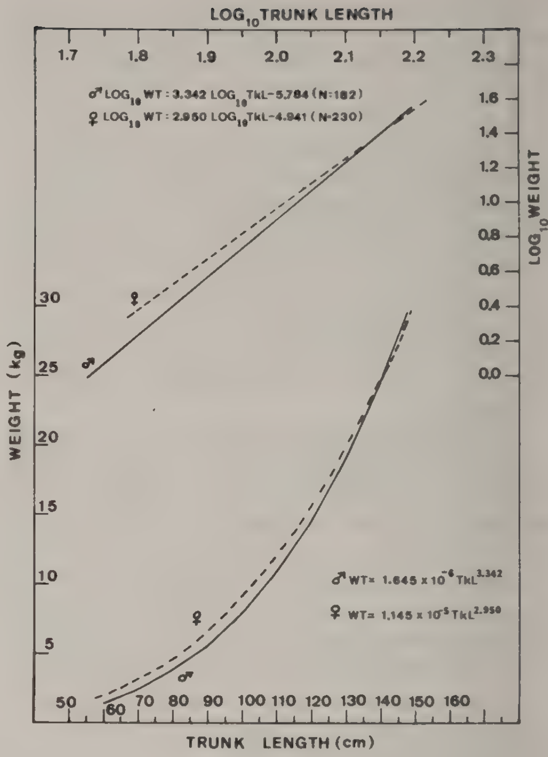

Figure 10.—Relationship of trunk length to weight for 412 Atlantic sailfish.

Table 4.—Results of fecundity studies for eight Atlantic sailfish ranging from 17.2 to 27.4 kg (38.0-62.5 lb).

Specimen	Total wt[1] (kg)	Ovary wt[1] (kg)	Body wt[1] (%)	Ova/gram wt	Est. fecundity
VI-14'	18.1	2.3	12.7	467	819,412
VI-15'	17.2	2.0	11.6	555	750,000
Not recorded	28.4	ca 2.4	8.5	457	1,075,321
VIII-1'	28.1	ca 2.6	9.3	498	1,148,918
VII-14'	19.1	2.0	10.5	890	1,557,574
IX-8	28.4	ca 2.3	8.1	616	1,297,850
VIII-3'	23.1	1.9	8.2	580	919,300
VI-17'	22.2	2.3	10.4	462	891,270

[1] Fresh weights recorded during field examination.

Initial observations from plankton collections confirm that sailfish spawn throughout summer. Larval and juvenile istiophorids 3 to 105 mm total length were collected during April through October. ''Ripe'' females were also prominent among adults sampled during May through September (Fig. 11). Spawning appears to be intense in mid-May through September. Two peaks were apparent during the spawning seasons (Fig. 11). A preliminary microscopic examination of gonadal tissue from ''ripe'' specimens and variation in the ovaries' percent of total body weight and number of ova per gram weight of ovary suggest multiple spawning.

ACKNOWLEDGMENTS

Special appreciation is expressed to John Rybovich, Jr., who helped organize and establish a field laboratory in West Palm Beach. Mr. Rybovich has been a constant source of help and enthusiasm during the entire project. Frances Doucet and staff of the West Palm Beach Fishing Club provided professional and secretarial services. The Phipps Foundation and Don J. S. Merten (Tournament of Champions winner, 1972) have provided financial assistance through cooperation with Game Fish Research Association, Inc. of West Palm Beach. Appreciation is extended to all anglers, sport fishing captains, and other local interests who directly or indirectly contributed to the project's success but who are too numerous to mention by name.

I am indebted to Al Pflueger, Jr. and James D. Smith of Pflueger Taxidermy for providing fresh specimens. Walter C. Jaap provided photographs of spines and spinal sections and Henry Kamiya drafted figures. Robert M. Ingle, Edwin A. Joyce, Jr., Robert W. Topp, Charles R. Futch, and especially Dale S. Beaumariage provided guidance and editorial review.

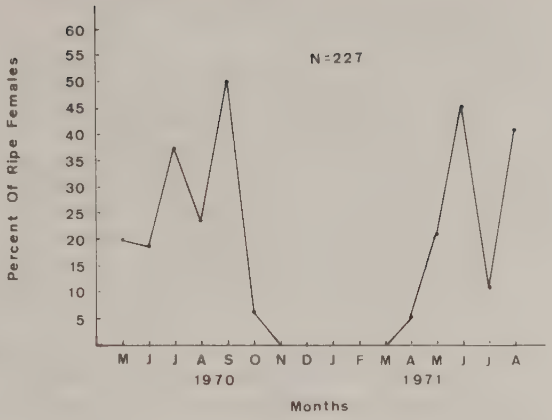

Figure 11.—''Ripe'' sailfish expressed as a percentage of total females examined monthly.

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Some Biological Observations of Billfishes Taken in the Eastern Pacific Ocean, 1967-1970

MAXWELL B. ELDRIDGE and PAUL G. WARES[1]

ABSTRACT

From 1967 through 1970 sport-caught billfishes were sampled at Mazatlán, Sinaloa; and Buena Vista, Baja California, and at San Diego, California. Lengths, weights, morphometrics, meristics, and gonad data were gathered on a total of 2,056 striped marlin, 821 sailfish, 61 blue marlin, and 1 black marlin. This paper presents information on reproduction, average length and condition factor, food habits for 1970, and notes on parasites.

Developing gonads were found only in the Mexican fish. Our data on reproduction indicated that both striped marlin and sailfish spawn once per year with peak spawning activity probably in June and July. There is also the possibility that sailfish spawn in other months. First maturity in striped marlin and sailfish occurred in the 155-165 cm eye-fork length class. Fecundity estimates ranged from 2 to 5 million eggs for four sailfish and from 11 to 29 million eggs for three striped marlin. It appears tnat striped marlin move offshore from the Mexican coastline to spawn while sailfish remain closer to shore.

Much of the interest in billfishes in the eastern Pacific Ocean stems from their popularity among sport fishermen. Commercial fishermen have also been interested in the billfish resources as indicated by their extensive and continuous operation in this area since 1956 (Suda and Schaefer, 1965). Since 1963 this fishery has concentrated off Mexico where it is directed primarily at striped marlin *(Tetrapturus audax)* and sailfish *(Istiophorus platypterus)* (Kume and Schaefer, 1966; Kume and Joseph, 1969a). Throughout the history of the billfish fishery in the eastern Pacific no attempt has been made to manage these resources; this is partly due to the lack of information on the life history and population dynamics of these fishes. This report provides data gathered from billfishes landed at sportfishing sites in southern California and Mexico from 1967 to 1970. Specimens were examined at San Diego, California; Buena Vista, Baja California; and Mazatlán, Sinaloa, Mexico (Fig. 1). A total of 2,056 striped marlin, 821 sailfish, 61 blue marlin (*Makaira nigricans*) and 1 black marlin (*M. indica*) were sampled. This paper is one of a series of publications describing the results of these studies. Evans and Wares (1972) published information of the food habits of fish collected in 1967-1969, and another paper (Wares and Sakagawa, 1973) has been prepared to present meristic and morphometric analyses.

The purpose of this paper is primarily to present

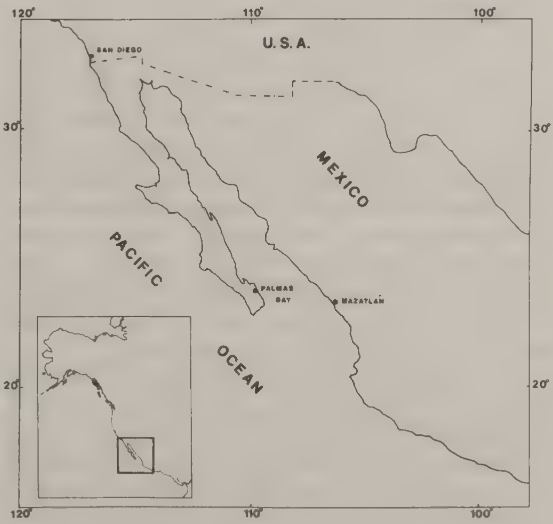

Figure 1.—Location of the three billfish sampling sites.

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[1] NOAA, National Marine Fisheries Service, Tiburon Fisheries Laboratory, Tiburon CA 94920.

data relating to sexual maturation and to make inferences on the reproductive biology of striped marlin and sailfish. The numbers of blue and black marlin were insufficient to add significantly to the knowledge of these species. We also present notes on food habits as observed from data collected in 1970, seasonal abundance, and parasites.

Because of the long established fishery for billfishes in the western and central Pacific, most billfish reproduction information has been derived from that area (Nakamura, 1932, 1940, 1949; Ueyanagi, 1959; Yabe, 1953; Honma and Kamimura, 1958). Merrett (1970, 1971) and Williams (1963, 1964, and 1970) reported on the Indian Ocean billfishes and concluded they are closely related to those in the western Pacific. We have encountered only two major publications (Kume and Joseph, 1969b; Yurov and Gonzales, 1972) dealing with reproduction of billfishes east of long. 130°W.

SEASONALITY

All four of the species studied occur regularly at Mazatlán and Buena Vista where they exhibit seasonal cycles of abundance. San Diego is near the northern extreme of istiophorid ranges on the eastern Pacific coast and except possibly in the warmest years, striped marlin is the only species captured there. The occurrence of striped marlin is highly seasonal.

Based on records kept by several resorts (1963-69) in the Palmas Bay area of Baja California (the area surrounding Buena Vista) and at Mazatlán (1967-69), sailfish and striped marlin show distinct patterns of seasonal abundance. Though these data are probably not highly accurate, the trends (Fig. 2 and 3) agree with our personal observations and with data provided by the Departamento de Tourismo, Terr. Baja California Sur. Seasonalities for blue and black marlin are not presented because of the low numbers in the catch records and because of persistent confusion in the identification of the two species. It appeared, however, that blue marlin were most abundant from late summer through winter, at least in the Palmas Bay area.

Peak abundance of both striped marlin and sailfish tended to occur later in the year at Palmas Bay than Mazatlán. At each location, the time of maximum abundance of sailfish occurred later than that of striped marlin. The seasonal occurrence of striped marlin is much more restricted at San Diego than in Mexico with no fish being caught before July 1 or after December 1. Records of striped marlin landed at three sportfishing clubs in San Diego from 1963 to 1970 show the peak catch to vary between late August and early October. The timing of the apparent abundance of striped marlin off San Diego is believed to be correlated with surface water temperatures (Squire, 1974a).

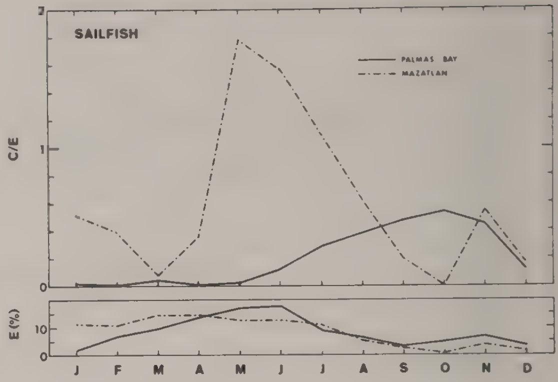

Figure 2.—Catch per unit effort (number per boat-day) and percent effort for sailfish sport fishery from Palmas Bay (1963-1969) and Mazatlán (1967-1969).

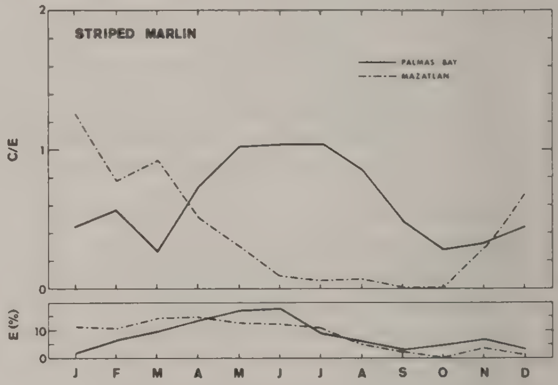

Figure 3.—Catch per unit effort (number per boat-day) and percent effort for striped marlin sport fishery from Palmas Bay (1963-1969) and Mazatlán (1967-1969).

REPRODUCTION

Collection and Processing of Samples

Gonad weights and fish length and weight were measured and sex noted of each fish examined. During 1969 and 1970 core samples of ovaries were also taken. Also in 1970, Japanese longliners provided us with gonads and detailed information of six additional mature striped marlin caught near the Revillagigedo Islands (lat. 19°N, long. 111°W).

Field sampling of specimens involved examination of fishes during the same day in which they were caught. Each fish was weighed and measured (eye-fork length). The body cavity was then opened and the gonads excised. Adhering fascia were removed and the gonads weighed. In 1970 the length and volume of each gonad was measured. During 1969 and 1970 ovarian tissue was sampled with a cork borer following a method used by Yuen (1955) wherein two transverse borings through the ovary are made at approximately ⅓ the distance from each end. These two samples from each fish were preserved in Gilson's fluid (Simpson, 1951), which rendered the ova much easier to measure and handle. This treatment appears to have no obvious differential effect on the ova diameters or shape (Schaefer and Orange, 1956).

The samples were kept in Gilson's fluid from 2 to 18 mo during which time the ova became separated from the ovarian tissue. Each sample was then gently stirred and a random sample of ova was measured with an ocular micrometer at 30× magnification. Ova diameter measurements were taken on whatever axis fell parallel to the micrometer graduations. Several authors (Clark, 1925, 1934; June, 1953; Otsu and Uchida, 1959; and Yuen, 1955) have concluded that random measurements regardless of the axis produced reliable results.

Because differential maturation of ova was found in bigeye tuna (Yuen, 1955) we took integrated samples with the cork borer. Later examination of mature striped marlin and sailfish ovaries, however, showed no evidence of either cross-sectional or longitudinal variation in ova size within ovaries. We tested for cross-sectional variation by taking radial subsamples from a 10 mm thick transverse section near the middle of one of the largest, most mature striped marlin ovaries. The ova diameter frequency distributions (Fig. 4) of three samples radiating from the center were similar. Likewise, anterior, middle, and posterior subsamples from two striped marlin and one sailfish ovaries showed no evidence of longitudinal variation (Fig. 5).

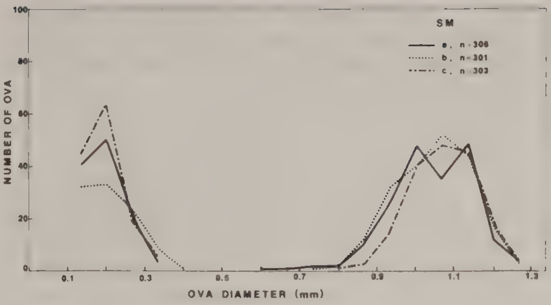

Figure 4.—Ova diameter frequency polygons of subsamples taken near the middle of a mature striped marlin ovary; **a**—central, **b**—intermediate, **c**—peripheral.

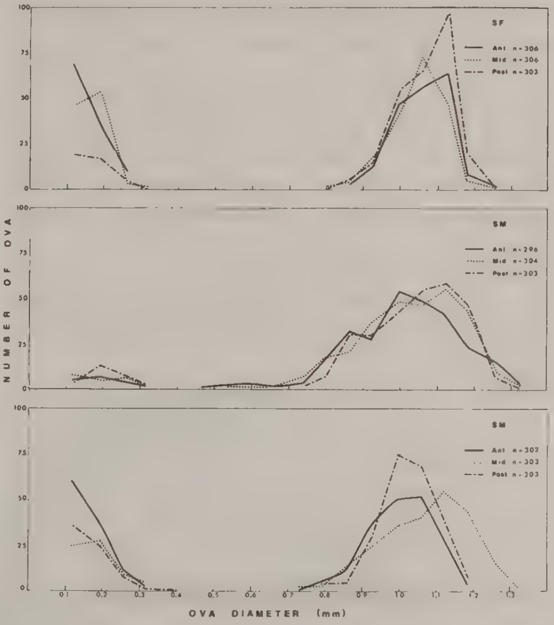

Figure 5.—Ova diameter frequency polygons from one mature sailfish and two striped marlin. Samples were taken from the anterior, middle, and posterior areas of the left ovary.

The 95th centile egg diameter was determined from the size frequency distribution of 300 eggs measured at random as described by Schaefer and Orange (1956). "Maximum ova diameter" as used by us was the largest size class interval (0.066 mm increments) containing ova from a sample of 50 ova measured at random.

Description of Gonads

Detailed description of the gonads and spawning products of billfishes were published by Merrett (1970) and La Monte (1958). In our studies we found strong evidence of gonadal assymetry (Table 1). For striped marlin, the left gonad averaged larger than

Table 1.—Percent frequency of specimens in which the left gonad was larger in weight than the right; left gonad expressed as average percentage of combined gonad weight and length.

	Freq. L>R	Left gonad as percent of combined		
	(%)	Weight	Length	*N*
Striped Marlin				
Male	80	53.1	53.7	40
Female	95	60.5	54.5	44
Sailfish				
Male	73	48.5	53.3	11
Female	79	55.5	52.9	24

the right in both sexes. The left ovary of sailfish also averaged larger but the left testis averaged smaller in weight. Females exhibited the greatest gonadal asymmetry and the difference in size between right and left ovaries was often obvious without measurement. Williams (1963) observed similar differences in Indian Ocean striped marlin with the left gonad always larger in both length and displacement volume.

Several noteworthy gonadal abnormalities were also seen. In ten striped marlin, five sailfish, and one blue marlin, one ovary was lacking; in two striped marlin and one sailfish one testis was lacking. This phenomenon can result from the fusion of the two gonad primordia during development, or simply from the failure of one gonad to develop (Hoar and Randall, 1969). In one striped marlin the ovary had proliferated into many different sized lobes filling much of the coelomic cavity (Fig. 6). It was filled with large eggs which were visibly misshapen. Another striped marlin was noted to have a testis which had divided into separate anterior and posterior lobes. Four ovaries were tumorous, brown-red in color, consisting of dense, odiferous tissue. Penellid copepods were found encysted in the gonads of three striped marlin and one sailfish.

Measures of Sexual Maturity

The general problem of finding an accurate and efficient means of measuring sexual maturity in fishes has resulted in the development of many techniques. Testes have not been found to be suitable because of problems encountered in measuring accurately their sex products (June, 1953). In addition, Merrett (1970) has shown by histological examination that unlike the case in most teleosts, there is differential maturation of spermatozoa in the testicular lobules of billfishes. There is thus only a small

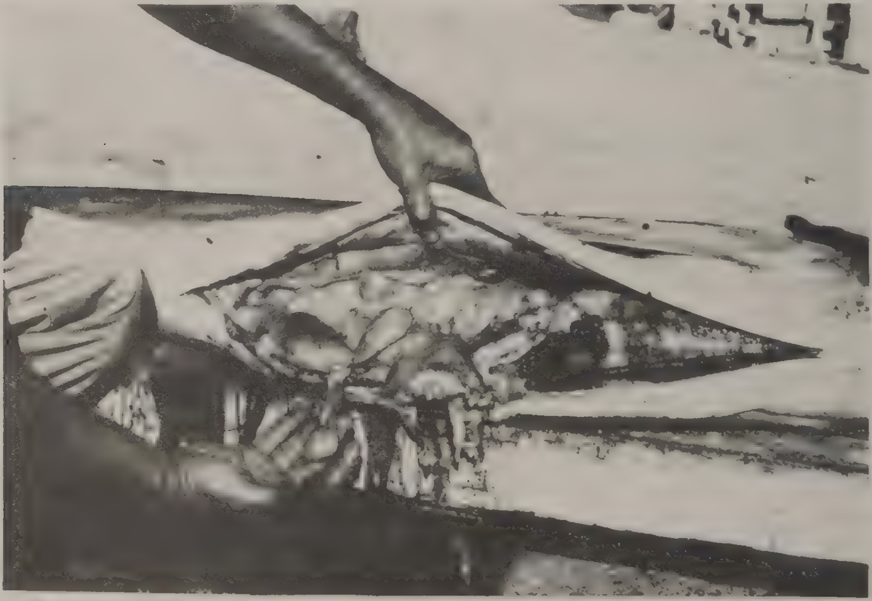

Figure 6.—Illustration of an abnormal striped marlin ovary with different sized lobes throughout the coelomic cavity.

overall seasonal increase in size of the testes, and some milt is usually present throughout the year.

On the other hand, the ovary as an indicator of maturity has been well documented (Clark, 1925, 1929, 1934; Hickling and Rutenberg, 1936). As oogenesis proceeds, characteristic changes occur which can be easily detected macroscopically or microscopically. We therefore chose to use ovarian characteristics to represent maturity of billfishes in this study.

The most precise method of determining the stage of ovarian maturity is to histologically examine the tissues as performed by Merrett (1970) or Moser (1967). This procedure, however, is lengthy and time-consuming. Another reliable technique is to measure a large number of ova from the same ovary, a method used for many species (Clark, 1929, 1934; June, 1953; and Brock, 1954). This method is based on the assumption that as the spawning season progresses, the group or groups of maturing ova will be distinguished as advancing modes in size-frequency distributions. This method is also time-consuming and laborious, but has a definite advantage in characterizing the frequency of spawning when a fully mature specimen is examined. When many fish are examined over a time interval, the progression of the modes of developing ova may provide information on the rate of maturation, time of spawning, and size at maturity. Two variations of this process which require the measurement of fewer ova are the use of "maximum ova diameter" (Otsu and Uchida, 1959) and the position of the 95th centile (Schaefer and Orange, 1956). The latter is particularly useful when the exact position of the developing mode is difficult to distinguish, as in early maturation stages.

Indirect methods to measure sexual maturity involve the relationship between some measure of the fish's size (either length or weight) and gonad weight. The use of fish length assumes that fish weight is nearly proportional to the cube of the length, a true situation with regard to the billfishes in this study as determined by length-weight analyses for eastern Pacific billfish. It is also assumed that fecundity is proportional to size. Kume and Joseph (1969b) have plotted ovary weight versus eye-fork length and also utilized the gonad index *(GI)* computed as

$$GI = (W/L^3) \cdot 10^4$$

where

W = total weight of gonads in grams, and
L = eye-fork length in cm.

Table 2.—Regression of maximum ova diameter and 95th centile of ova diameter on gonad index (n = sample size, r = coefficient of correlation, b = slope, a = y axis intercept.)

	n	r	b	a
Striped Marlin				
95th centile on GI	31	0.936*	3.02	1.46
Max. ova diameter on GI	269	0.797*	3.78	1.48
Sailfish				
95th centile on GI	21	0.913*	3.91	2.47
Max. ova diameter on GI	184	0.859*	4.78	3.43

*Significant at 0.01 level.

Merrett (1971) used another type of gonad maturation index which related the macroscopic appearance (color, yolk presence, egg diameter, and general appearance) of the gonad to recognizable stages in its histology.

To evaluate these different measures of maturity and to determine the degree of correlation between them, we applied regression analyses to our data (Table 2). As can be seen, the gonad index is highly correlated. In each of the four regressions, the correlation coefficients exceeded the 0.01 significance levels when tested against a Student's t-distribution. The lower r values for regression of maximum ova diameter on gonad index can be explained by the fact that maximum egg diameters do not always represent the size of the advanced mode. For example, the presence of a few residual eggs in an ovary which is in the resting or early maturation stages will not reflect the true stage of development of the ovary.

We have included both direct and indirect methods to analyze the spawning of striped marlin and sailfish. But, based on the above comparison and considering the time and manpower costs and the degree of accuracy desired, we conclude that the gonad index represents the most practical indicator of the stage of sexual maturity for a study of this type.

Size at First Spawning

The reported size at which striped marlin attain sexual maturity varies little among previous studies. Merrett (1971) reported first maturity at 140-160 cm eye-fork length. This agrees with the conclusion of Williams (1963). Kume and Joseph (1969b) stated that individuals greater than 160 cm from the eastern Pacific regularly occur in the spawning group (3.0 *GI)*, however, they did collect a mature specimen in the 148-cm class.

Our criteria for evidence of sexual maturity were based on a minimum egg diameter and a minimum gonad index. Fish with maximum ova diameters equal to or greater than 0.3 mm were considered mature based on the work of Merrett (1970) who considered eggs of this size as maturing, having completed yolk and chorion formation. We somewhat conservatively chose $GI = 1.0$ as the other criterion based on our data (Fig. 7 and 8) which show that no gonad index exceeded 1.0 in Quarter I and, further, the gonad indices for immature fish below 145-150 cm in Quarter II were remarkably consistent and did not exceed 0.3. The increase in average gonad index with increasing fish lengths between 150 and 190 cm in Quarter II suggests that larger fish either mature earlier or have larger gonad index values at given maturity stages than smaller fish. The presence of higher gonad indices for large fish in Quarter I than those of small fish in both Quarters I and II suggests that the latter is the case. Based on these criteria first maturity of striped marlin occurred in the 155-165 cm length classes and in the 160-165 cm length classes of sailfish (Fig. 7, 8, 9, 10).

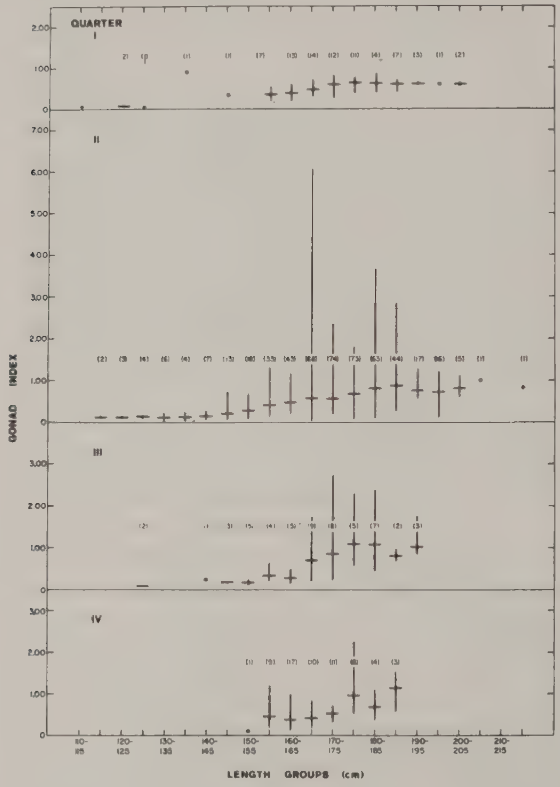

Figure 7.—Striped marlin gonad indices versus eye-fork length groups presented in quarters of the year. Numbers of striped marlin sampled are given in parentheses.

Frequency of Spawning

Simultaneous presence of both mature, nonatretic ova in the lumen and developing ova in the follicles is possible evidence of multiple spawning. However, lack of these conditions does not necessarily rule out multiple spawning. We plotted ova diameter frequency polygons of 300 ova from specimens with the highest gonad indices in each 2-wk period throughout 1969 and 1970. In addition, larger numbers of eggs were measured for one striped marlin and two sailfish, which had high gonad indices (Fig. 11). We found no indication of multiple spawning.

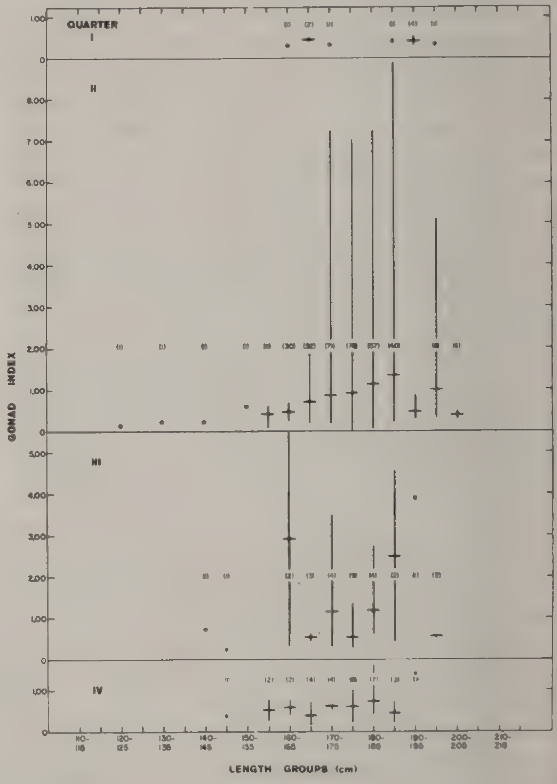

Figure 8.—Sailfish gonad indices versus eye-fork length groups presented in quarters of the year. Numbers of sailfish sampled are given in parentheses.

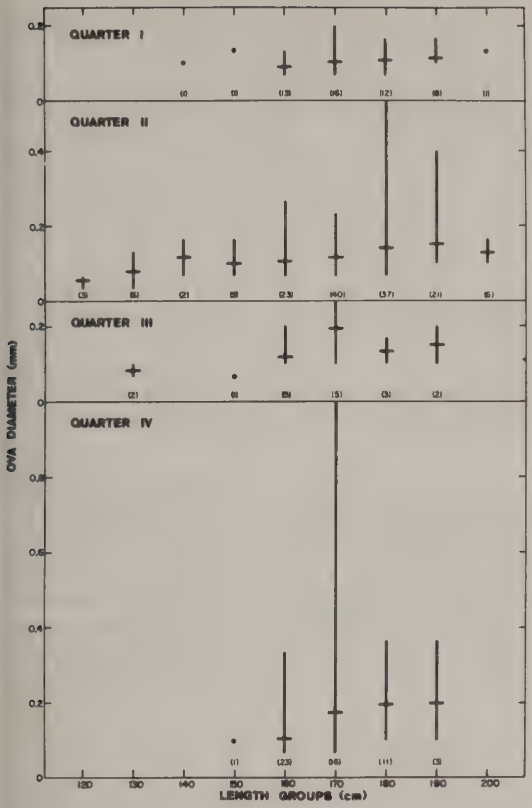

Figure 9.—Striped marlin ova diameters versus eye-fork length groups presented in quarters of the year. Numbers of striped marlin sampled are given in parentheses.

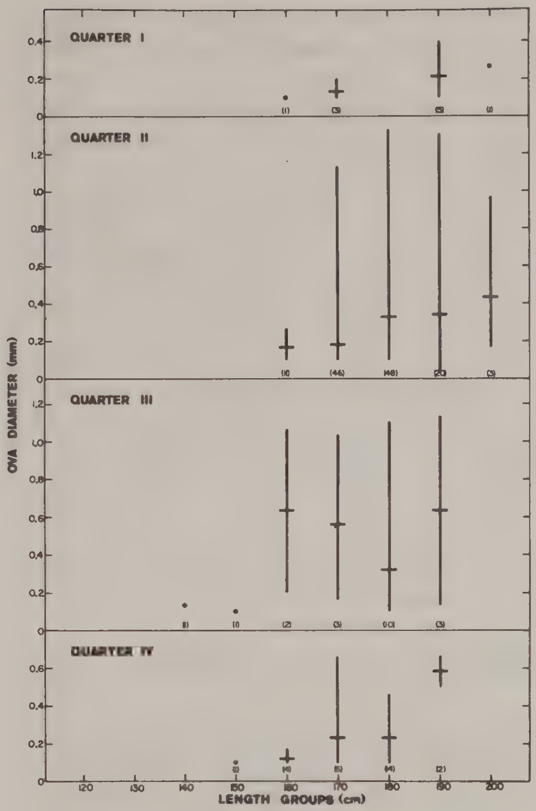

Figure 10.—Sailfish ova diameters versus eye-fork length groups presented in quarters of the year. Numbers of sailfish sampled are given in parentheses.

Fecundity

Little information is available on the fecundity of striped marlin or sailfish. Nakamura (1949) conservatively stated for billfishes in general that fecundity ranges from 1.0 to 1.2 million eggs depending on size and species. Merrett (1971) estimated a fecundity of 12 million eggs for an Indian Ocean striped marlin of 182 cm eye-fork length, with an ovary weight of 1.53 kg and a mean maximum egg diameter of 0.470 mm. In the central Pacific, Gosline and Brock (1960) estimated 13.8 million eggs for one striped marlin ovary.

We estimated the fecundities of four fully mature sailfish and three striped marlin by subsampling by weight. All specimens had high gonad indices and the striped marlin were specimens with the largest

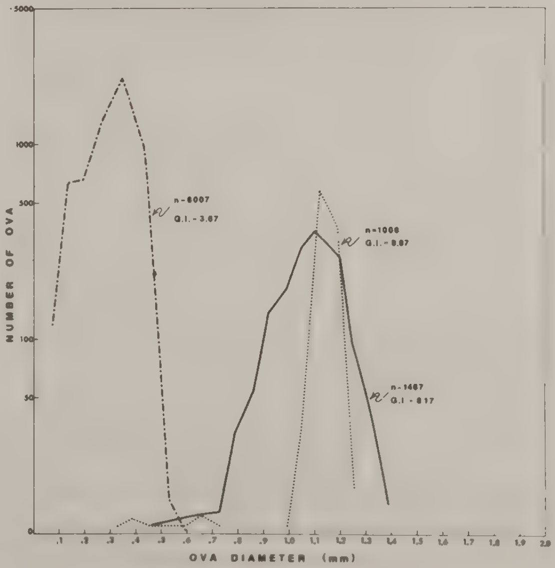

Figure 11.—Size frequency polygons for two mature sailfish (righthand curves) and one mature striped marlin.

ovaries encountered in this study. The fecundity estimates (Table 3) ranged from 11.3 to 28.6 million eggs for striped marlin and from 1.8 to 5.1 million eggs for sailfish.

Table 3.—Fecundity and related information on sailfish and striped marlin from the eastern North Pacific collected in 1969 and 1970.

	Gonad Index	Eye-Fork Length (cm)	Ovary Weight (gm)	Maximum Ova Diam. (mm)	Fecundity Estimate (million eggs)
Sailfish	3.7	185	2359	1.2	1.8
	5.5	163	2359	0.9	2.4
	7.0	176	3810	1.3	3.0
	8.9	187	5760	1.3	5.1
Striped Marlin	4.42	180	2580	0.6	11.3
	8.17	150	2760	0.6	17.2
	9.53	155	3550	0.6	28.6

Spawning Season and Locality

We are aware of only two publications that deal with spawning seasons of striped marlin and sailfish in the eastern Pacific (Kume and Joseph, 1969b and Yurov and Gonzales, 1972). Kume and Joseph (1969b) found that the highest frequency of striped marlin in spawning condition occurred in Quarter IV in the southern hemisphere and in Quarter II in the northern. Some were also in spawning condition in Quarter III in the northern hemisphere. These authors concluded that two spawning seasons existed at opposite times of the year in the northern and southern latitudes. This spawning pattern was also noticed in the western Pacific (Ueyanagi, 1959; Honma and Kamimura, 1958) and in the Indian Ocean (Williams, 1963; Merrett, 1971).

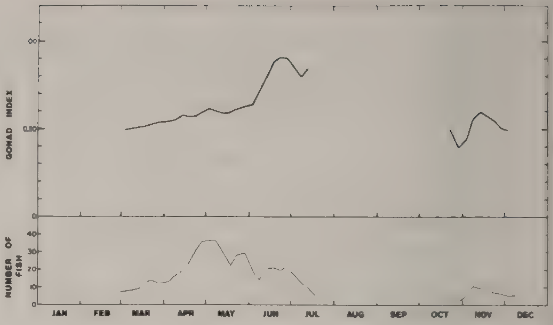

Figure 12.—Mean gonad index distribution and the number of striped marlin sampled by month from Buena Vista and Mazatlán.

Our data (Fig. 12 and 13) show a gradual increase

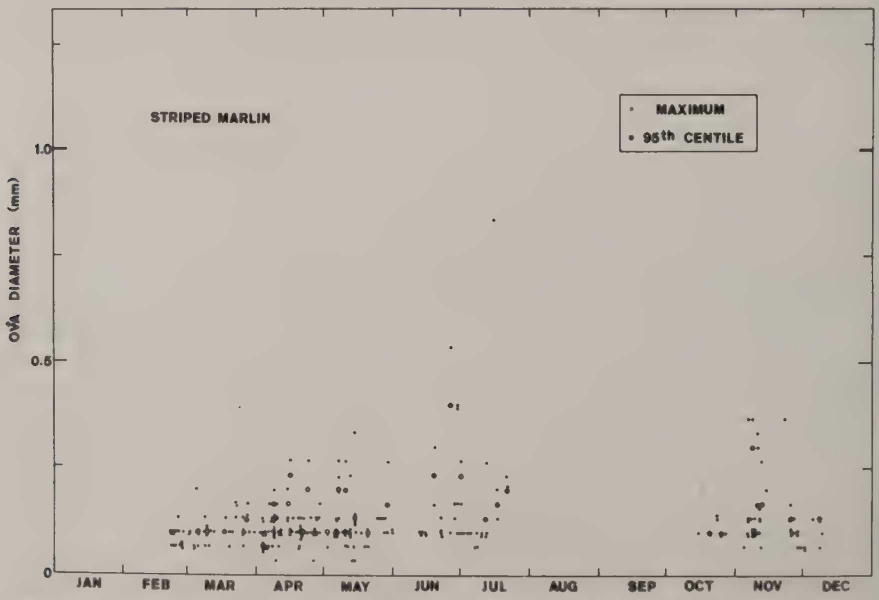

Figure 13.—Maximum ova diameter and 95th centile distributions by month from striped marlin ovaries sampled by Buena Vista and Mazatlán.

in maturation through June and July, at which time our sampling stopped. Several factors suggest that striped marlin move away from our sampling area at this time. Migration patterns indicated by Kume and Joseph (1969a) and Squire (1974b) showed that striped marlin move west-southwesterly from the coastal areas as the year progresses. Also, the data from the sport fishery (Fig. 2) show concentrations of striped marlin decreasing after March at Mazatlán and after July at Buena Vista. During July, Japanese longline fishermen have noted fully mature striped marlin in increased concentrations around the Revillagigedo Islands (G. Adachi, pers. comm.). The fish appeared in pairs and when one was hooked the other would remain alongside until the fish was hauled aboard. This behavior was not noticed in other areas of the eastern North Pacific or during other times of the year. Ovaries provided to us by the longliners from that area were all ripe and ranged in gonad index from 4.42 to 9.53 and the ova diameters were all in excess of 1.25 mm.

Sex ratio for striped marlin showed a slight but not significant predominance of males at Mazatlán from late February to July. In the larger and seasonally later catches at Buena Vista, males tended towards 60% from April through early June. The ratio then remained close to 50% into August. The October-early November ratios were also near 50%. Off San Diego, male striped marlin averaged only about 30% up to late September but rose to almost 50% for the rest of the season.

From these data it is logical to suggest that striped marlin migrate away from the coastal areas near the Gulf of California to spawn during July and possibly August. Females sampled at San Diego in August were in a post spawning condition and all had gonad indices less than 1.0.

Available evidence suggests that sailfish spawn nearshore in the eastern North Pacific with a northward progression of spawning activity during the year. Kume and Joseph (1969b) noted that some sailfish from Costa Rica coastal waters were in spawning condition from February to March. At the same time sailfish from offshore waters from lat. 0° to 15° were immature. Yurov and Gonzales (1972) reported spawning in the Gulf of Tehuantepec extending from February to April. We measured 36 larval and juvenile sailfish collected by Scripps Institution of Oceanography and the National Marine Fisheries Service along the Central American coast. Estimated spawning dates for these specimens based on back calculations using the growth rates of de Sylva (1957) indicated spawning of Costa Rican specimens from December through March, Guatemalan specimens mostly from January through April (with two in August), and Mexican specimens from April through November.

Our data conform to this pattern. Sailfish began to mature in late May and reached spawning condition in June and July (Fig. 14 and 15). The average gonad index showed a rapid decline in July, but this may be an artifact of a sharply reduced sample size. The ova remained large.

From April through July the sex ratio of Mazatlán sailfish remained close to 50%. Slightly more females than males were found until early June, after which time the ratio tended towards males. The smaller numbers of sailfish caught in Palmas Bay were predominantly female with males never exceeding 50%.

PARASITES

Among the incidental observations of parasites perhaps the most significant was the discovery of *Philichthys xiphiae* Steenstrup in the opercular bone in several striped marlin at Buena Vista and Mazatlán. Previously this species had been reported from the mucous canals of swordfish *(Xiphias gladius)* but not from any of the istiophorids and not from the eastern Pacific. The parasites were embedded in the preopercle just beneath the skin. The differences between parasitized and normal bones are readily seen in the x-ray photos in Figure 16. Other possible infection sites (bones) were not checked for this parasite nor were other billfish species.

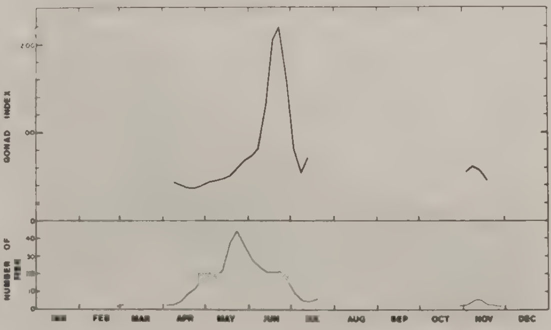

Figure 14.—Mean gonad index distribution and the number of sailfish sampled by month from Buena Vista and Mazatlán.

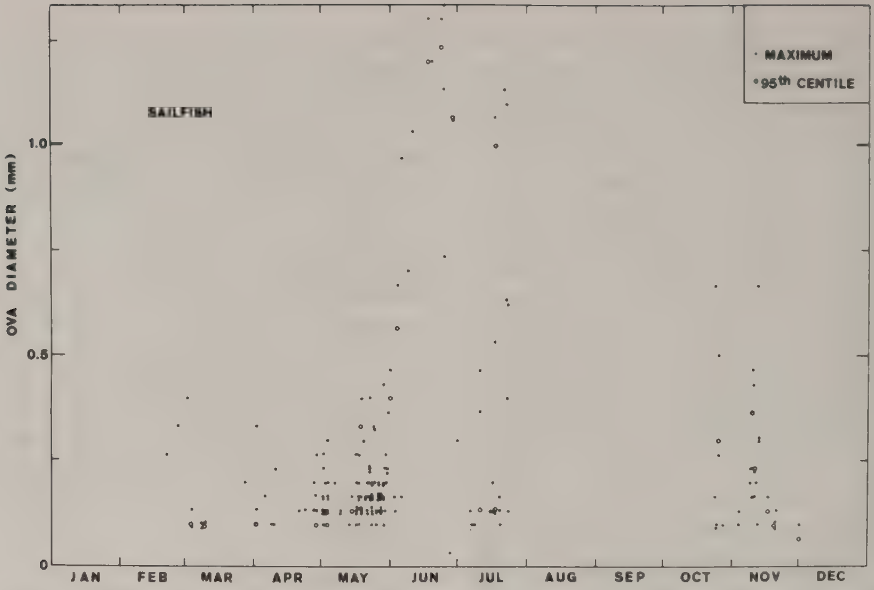

Figure 15.—Distribution of sailfish maximum ova diameters and 95th centiles by month from Buena Vista and Mazatlán.

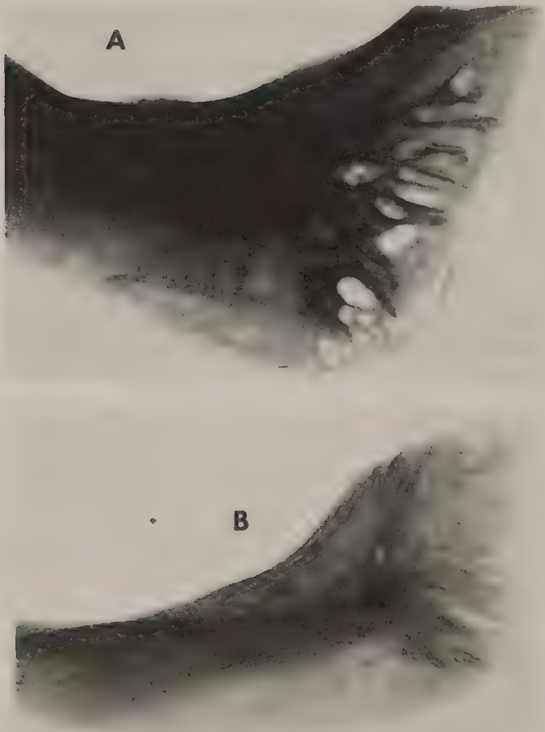

Figure 16.—X-ray photos of preopercular bones of striped marlin from Buena Vista showing (**A**) cavities caused by *Philichthys xiphiae* (**B**) a non-parasitized bone.

Caligoid copepods (some identified as *Pandarus* sp.) were common on the body surface and often very numerous, particularly in the ventral region just anterior to the anal fin. Large concentrations of these parasites appeared to irritate the skin, causing redness. White capsalid trematodes were commonly seen on the body surface. A different species of capsalid was found commonly in the nasal cavities. Isopods (some identified as *Nercila* sp.) were quite common on the body surface (usually on the fins) of sailfish at Mazatlán. Up to 57 isopods were recovered from a single sailfish. Nematodes were present, often numerous, in most of the billfish stomachs examined.

FOOD HABITS

Evans and Wares (1972) presented the data for 1967-1969. The contents of additional stomachs examined in 1970 (Table 4) are analyzed below. Table 5 presents the new data as percent occurrence and percent of total food volume. Table 6 compares the top ranked food items based on volume from the two studies. Except at San Diego, where the sampling dates were similar (August-October) in both studies, the comparison is between seasons as well as between years. The 1970 sampling in Mexico was from October through December whereas most of the earlier data was gathered from April through July.

The major departures from the results found in the previous study were the low importance of anchovies in San Diego striped marlin and of squid in Buena Vista sailfish stomachs.

Table 4.—Sample sizes and condition of billfish stomachs sampled during 1970.

	Striped Marlin			Blue Marlin	Sailfish
	SD	BV	Maz	BV	BV
No. Stomachs					
Total	37	59	8	15	33
With Food	20	37	4	8	22
Empty	16	5	1	2	2
Regurgitated	1	17	3	5	9
Total Vol. of Food (ℓ)	7.35	8.25	0.97	1.86	6.83

ACKNOWLEDGMENTS

We are indebted to representatives of resorts and clubs who permitted us to examine specimens of billfishes: Col. Eugene Walters, proprietor of Rancho Buena Vista; Bill Heimpel, proprietor of the Star Fleet at Mazatlán; Lois Ibey, Secretary of the San Diego Marlin Club. We are grateful to Lic. Ricardo Garcia Soto, Director of the Departamento de Tourismo de Baja California Sur for making available the reported catch data of sportfishing resorts in Baja California. We are also grateful to the managers of the following Baja California resorts for effort data: Bahîa de Palmas, Rancho Buena Vista, Hotel Palmilla, Hotel Cabo San Lucas and Hacienda Cabo San Lucas. Several fleets at Mazatlán kept records of catch and effort for us and special thanks are due Bill Heimpel for his efforts. Other members of our staff who helped us collect and analyze the data were: Larry Coe, Dan Eilers,

Table 5.—Food species of billfishes observed in 1970 (% Occurrence/% Volume).

	Striped Marlin			Blue Marlin	Sailfish
	SD	BV	Maz	BV	BV
ALGAE	7.5/0.5	—	—	—	—
INVERTEBRATES					
Crustacea					
Decapods	—	3.0/0.2	—	—	—
Cephalopoda					
Argonauta sp.	—	—	50/6.2	—	—
Squid	5.0/0.4	62/24	25/1.2	13/1.1	12/3.1
FISHES					
Elasmobranchs	2.5/T	—	—	—	—
Clupeidae					
Etrumeus teres	—	43/39	—	—	18/24
Sardinops sagax	5.0/3.1	—	—	—	—
Opisthonema sp.	—	—	—	—	2.0/0.3
Engraulidae					
Engraulis mordax	2.5/2.2	—	—	—	—
Myctophidae	—	3.0/0.7	—	—	2.0/0.5
Scomberesocidae					
Cololabis saira	7.5/23.8	—	—	—	—
Atherinidae					
Atherinopsis californiensis	2.5/16	—	—	—	—
Exocoetidae					
Cypselurus californicus	2.5/0.2	—	—	—	—
Unidentified sp.	—	—	—	13/0.4	—
Fistularidae					
Fistularia sp.	—	—	—	—	8.2/21
Syngnathidae	—	—	25/0.4	—	—
Echeneidae					
Remora brachyptera	—	—	—	12/1.6	—
Carangidae					
Caranx caballus	—	3.0/0.8	—	—	2.0/0.6
Decapterus hypodus	—	3.0/1.7	—	—	2.0/4.4
Hemicaranx sp.	—	5.0/1.0	—	—	—
Trachurus symmetricus	38/62	—	—	—	—
Unidentified sp.	—	3.0/1.2	—	—	8.2/1.0
Coryphaenidae	—	—	—	—	2.0/10
Scorpidae					
Medialuna californiensis	5.0/2.4	—	—	—	—
Chaetodontidae	—	—	75/12	—	—
Mugilidae					
Mugil cephalus	—	—	25/79	—	—
Sphyraenidae					
Sphyraena sp.	—	3.0/2.3	—	—	—
Scombridae					
Auxis thazard	—	3.0/0.4	—	37/36	6.1/13
Euthynnus lineatus	—	5.1/17	—	12/19	8.2/13
Sarda chiliensis	2.5/0.8	—	—	—	—
Scomber sp.	—	3.0/2.1	—	—	4.1/2.3
Unidentified sp.	—	—	—	25/39	—
Balistidae					
Balistes sp.	—	3.0/0.1	—	—	6.1/0.4
Tetraodontidae					
Sphoeroides sp.	—	3.0/2.2	—	—	—
Lagocephalus lagocephalus	—	19/6.4	—	—	10/4.0
Unidentified Fish	20/3.9	8/1.4	50/1.4	38/2.2	6.1/1.4

Table 6.—Comparison of major billfish foods in 1970 with those for 1967-1969 (n = no. of stomachs with food).

	STRIPED MARLIN				
	1967-1969			1970	
	Rank	Species	%Vol.	% Vol.	Species
San Diego		*n* = 116			*n* = 20
	1.	*Engraulis mordax*	60	62	*Trachurus symmetricus*
	2.	*Trachurus symmetricus*	27	16	*Atherinopsis californiensis*
	3.	*Cololabis saira*	5	8	*Cololabis saira*
Buena Vista		*n* = 303			*n* = 37
	1.	Squid	49	39	*Etrumeus teres*
	2.	*Etrumeus teres*	30	24	Squid
	3.	*Scomber japonicus*	7	17	*Euthynnus lineatus*
	4.			6	*Lagocephalus lagocephalus*
Mazatlán		*n* = 14			*n* = 4
	1.	Squid	63	79	*Mugil cephalus*
	2.	*Argonauta* sp.	7	12	*Chaetodon* sp.
	3.	*Balistes* sp.	7	6	*Argonauta* sp.
	4.	*Fistularia* sp.	5		
		SAILFISH			
Buena Vista		*n* = 14			*n* = 22
	1.	Squid	35	24	*Etrumeus teres*
	2.	*Etrumeus teres*	29	21	*Fistularia* sp.
	3.	*Fistularia* sp.	22	14	*Euthynnus lineatus*
	4.	*Naucrates ductor*	7	13	*Auxis thazard*
		BLUE MARLIN			
Buena Vista		No Data			*n* = 8
	1.			39	Scombrids (unidentified)
	2.			36	*Auxis thazard*
	3.			19	*Euthynnus lineatus*

Douglas Evans, Stewart Luttich, Howard Ness, and David Tolhurst. Roger Cressey identified *Philichthys xiphii* and Ernest Iversen identified the parasites *Pandarus* sp. and *Nercila* sp.

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Scientific Billfish Investigation: Present and Future Australia, New Zealand, Africa[1]

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ABSTRACT

I. Scientists, anglers, skippers, and mates investigate and apply the scientific method.

The importance of knowledge, organization, and skills required of the scientist, angler, skipper, and mate in order to bring about a better understanding of the billfish and better methods of catching billfish is discussed.

II. The need for more observations and recording of data.

The following data should be given important consideration: temperature, depth, time, winds, currents, strike-catch ratio, bait, and the ship's log; these topics are reviewed.

III. Scientific research projects for consideration in the future.

Potential research projects in Australia, New Zealand, and Africa are presented. Some projects worthy of consideration include: (1) breeding of black marlin at the Great Barrier Reef, Australia; (2) transplanting of small black marlin to a natural salt water lake for study and observation of growth and development (Australia); (3) migration studies by tracking (Australia, New Zealand, Africa); (4) general blood cell surveys (New Zealand); (5) general chromosome surveys (New Zealand); and (6) sensory and motor responses of billfish in relation to sight, smell, and pain (Africa).

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[1] This paper was presented orally, but only title and abstract were submitted for publication.

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Biology of Swordfish, *Xiphias gladius* L., in the Northwest Atlantic Ocean

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ABSTRACT

The present knowledge of the biology of swordfish in the northwest Atlantic ocean is summarized. Distribution of swordfish is bounded by 13°C surface isotherms with smaller (under 160 cm) fish in water above 18°C. Males are smaller (under 200 cm) than females and are more frequent in warmer, southern areas. Large fish make feeding excursions to the bottom, to depths of 500 m or more and temperatures 5-10°C. Females attain sizes of 550 kg and males 120 kg, but average size was 54 kg in 1970 commercial landings. Growth is thought to be rapid with weights of 4, 15, 40, 70, and 110 kg attained at annual intervals. Spawning is confined to warmer (over 24°C) southern waters. Tagging data (13 recoveries) suggest fish spend the summer in one locality and return there in subsequent years. High recoveries (18.3%) have been made of fish tagged while swimming free.

The biology and distribution of swordfish has been investigated by the staff of the Fisheries Research Board of Canada's Biological Station at St. Andrews, N. B. since 1958. This report summarizes the information obtained during this period from a large number of research cruises, from extensive shore sampling of the commercial catch, and from the available literature.

DISTRIBUTION

The geographical distribution of swordfish, *Xiphias gladius* L., in the northwest Atlantic Ocean varies considerably due to the marked seasonal variation in environmental conditions. In winter, the species is confined to the waters associated with the Gulf Stream (Fig. 1), where the surface temperature exceeds 18°C. However, in summer, as the edge of the Gulf Stream moves north and the temperature of the surface waters over the continental shelf increases, the fish are found over a much wider area. The summer range extends along the edge of the continental shelf from Cape Cod to the Grand Banks, with fish moving over the shelf in the western part, and, near the mouth of the Gulf of St. Lawrence, along the Cape Breton shore. Occasionally fish are found in the Gulf of St. Lawrence as far north as the Miramichi River, while the most northerly record on the west coast of Newfoundland appears to be Bonne Bay (Wulff, 1943).

The summer distribution is generally limited by the 13°C isotherm, with few fish encountered below 15°C. Distribution by size shows that there is a size differential in that larger fish are found in cooler water, with few fish under 90 kg round weight seen in water of less than 18°C.

Sex ratios also differ with temperature, as few males are found in the colder (under 18°C) water. In warmer water, males comprise some 25-30% of the catch. This difference in sex ratios may be partially explained by the smaller size of males since few

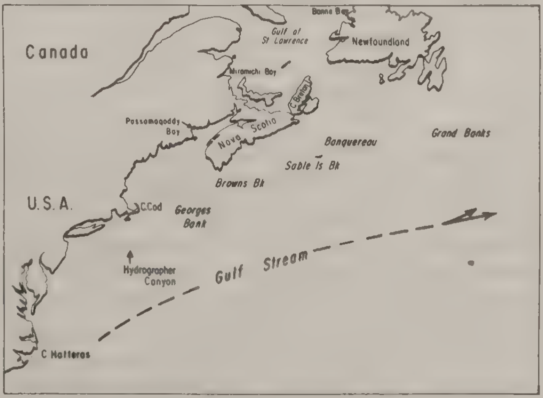

Figure 1.—Canadian commercial swordfish fishing areas.

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[1] Fisheries Research Board of Canada, St. Andrews, New Brunswick, Canada.

exceed 200 cm fork length (about 120 kg), and are, therefore, less likely to be found in cold water. However, the males may tend to remain in even warmer water as they predominate (67-100%) in catches farther south, particularly in the Caribbean and adjacent regions.

The variation in distribution by size in the northern regions is apparently due to differences in feeding habits coupled with temperature tolerances. Swordfish over deep water feed largely on surface animals (flying fish, etc.), local near-surface schooling species (herring, mackerel, etc.), mid-water, but usually vertically migrating species (lanternfish, barracudinas, etc.), and upon squids. In shallower water, large swordfish, whilst also taking near-surface species, make feeding excursions to the bottom where the temperature may be as low as 5-10°C, and feed upon redfish, hake, butterfish, and other benthic species. These fish then apparently return to the upper mixed layer while digesting their meal, presumably to obtain a higher body temperature, since there is no evidence of homoiothermy, or elevated values, in this species. It is at this time that fish may be seen near the surface on calm sunny days, conditions that result in water temperatures that are higher right at the surface. Swordfish harpooned at the surface either have full stomachs or empty ones. These latter are completely empty without even the normal complement of nematodes or fish and squid hard parts, a fact suggesting voiding of the contents while the fish struggled against the harpoon line. Swordfish have been observed from submersibles, at depths of 500 m or more, and even to have been apparently resting at, or near, the bottom. It is impossible to determine whether these fish were on temporary excursions into these depths and low temperatures, or whether they regularly remain in this environment.

SPAWNING

The reproductive cycle of swordfish in the northwest Atlantic appears to involve spawning to the south, in the Caribbean and adjacent areas, where the temperature exceeds 24°C. The vast majority of gonads from fish captured north of lat. 35°N (Cape Hatteras) have been in the quiescent stage, with ova diameters less than 0.18 mm. Maturing ova may exceed 1.0 mm. Occasional fish have been reported with ripening ovaries (Fish, 1926; FRB unpublished) but these are rare, numbering one or two a year, at most. Similarly some milt has been noted in a few males, but this is not necessarily a sign of imminent spawning. Fish (1926) estimated that a mature female contained 16 million eggs, while another specimen was calculated to contain 5 million.

SIZE

The largest swordfish, the size of which can be verified, was a fish of 915 lb. dressed weight (approximately 550 kg live weight) landed in Cape Breton. The average weight taken by the commercial fishery, however, was much less than this, being close to 120 kg (round) for harpooned fish, and in 1970, as low as 54 kg for all fishing methods. The average size had fallen considerably since the introduction of longlining in 1962 (Tibbo and Sreedharan, 1974). The size distribution of commercial landings during 1970 (Fig. 2) shows a peak frequency in the 41-50 lb (18.6-22.8 kg) dressed weight class. This is equivalent (× 1.326) to 55-66 lb (24.9-30.0 kg) round weight.

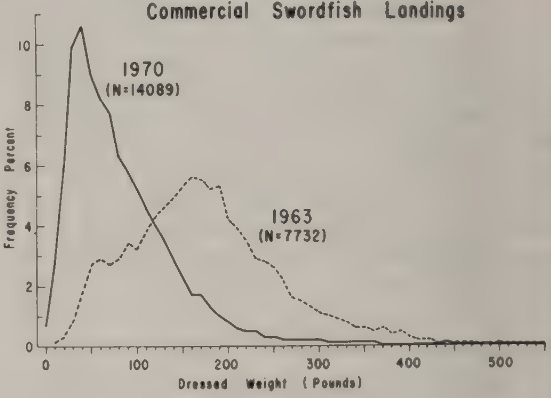

Figure 2.—Size distribution of swordfish landed in Canada in 1970. (Dressed weight to live weight conversion factor 1.326.)

SIZE/WEIGHT AND GROWTH

Analysis of the relationship between fork length (cm) and live weight (lb) ratio by the least squares method, indicates slope coefficients of 2.6-3.1 for different samples at different seasons, with correlation coefficients higher than 0.9

The rate of growth has been investigated in a number of ways but no firm figures are available. There are no scales in adults, the otoliths are minute, and, while the bony parts (vertebrae, operculae, fin rays) show rings, these do not appear to be consistently interpretable. Estimates from modal size frequencies, vertebral rings, and tagging data suggest a rapid growth rate with weights of 4, 15, 40, 70, and 110 kg after successive years for females. There are insufficient data to determine whether the smaller size obtained by males, relative to females, is due to a slower growth rate, or to a considerably shorter life span. The average size of 31 males for which detailed morphometric data were available was 147.2 cm and that of 134 females was 176.9 cm (fork length).

TAGGING

High recoveries (11 tags, 18.3%) have been made of the 60 swordfish marked by modified harpoon (Beckett, 1968). These fish were tagged while swimming free at the surface. In contrast, of the 146 fish taken on longline and then released, only 2 (1.4%) have been recaptured.

Migrations and Stock Identification

The spawning data, as judged from the occurrence of larvae, indicate considerable migration of swordfish between the northern feeding areas and southern reproductive zones (Markle, 1974). However, the separate nature of the actual areas where larvae have been found (Virgin Islands, Windward Islands, Windward Passage, Northwest Caribbean, Florida Straits, and Western Gulf of Mexico) suggests the possibility of some stock separation between these areas.

In the north, the tagging data (Table 1) for the 13 fish recaptured suggests that swordfish return to the same part of the summer feeding area in subsequent years. No tagged fish have changed the general locality either within, or between years, the maximum displacement being 179 miles and the recovery position for that fish is suspect. Furthermore, morphometric data suggests some heterogeneity between the fish on Georges Bank (Fig. 1) and those on the Grand Banks, during the summer. Additional studies that were being undertaken on this matter, particularly tagging, have been frustrated by the mercury-inspired cessation of commercial longlining.

ACKNOWLEDGMENTS

Many people have worked in the Large Pelagic Fish programme, and I particularly acknowledge S. N. Tibbo, Programme Head, and my many companions on sea cruises.

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Table 1.—Swordfish tag returns.

Released date	Area	Size (lb)	Date	Recovery Area	Size (lb)	Months out	Min. distance miles	Size change (lb)
9/9/1964	Georges	90 est.	12/ 7/1966	Georges	188 est.	21	60	+ 98
7/6/1966	Gulf Stream	70 est.	10/ 7/1969	Georges	156	37	128	+ 86
3/7/1968	Georges	160 est.	3/ 9/1970	Stellwagon	212	26	178	+ 52
27/7/1968	Sable	400 est.	11/11/1969	Sable	400+	16	7	0
27/7/1968	Sable	350 est.	2/10/1969	Sable	590	15	6	+240
29/7/1968	Browns	160 est.	4/10/1968	Browns	150 est.	3	28	− 10
13/7/1970	Georges	120 est.	20/ 9/1970	Georges	140 est.	2	59	+ 20
13/7/1970	Georges	140 est.	14/ 9/1970	Georges	n/a	0	5	n/a
13/7/1970	Georges	170 est.	19/ 7/1970	Georges	172	0	38	+ 2
13/7/1970	Georges	150 est.	11/ 9/1970	Georges	185	2	83	+ 35
13/7/1970	Georges	100 est.	13/10/1970	Georges	75 est.	3	92	− 25
13/7/1970	Georges	180 est.	27/ 7/1970	Georges	228	0	31	+ 48
4/8/1968	Georges	225 est.	30/ 8/1970	Georges	234	24	30	+ 9

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Some Morphometrics of Billfishes From the Eastern Pacific Ocean

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ABSTRACT

Length-weight and morphometric data collected over 4 yr (1967-70) from sport fisheries at three eastern Pacific locations are presented for striped marlin *(Tetrapturus audax)*, sailfish *(Istiophorus platypterus)*, and blue marlin *(Makaira nigricans)*. The data were gathered from San Diego, California (U.S.A.), Buena Vista, Baja California Sur (Mexico), and Mazatlán, Sinaloa (Mexico).

Regression of eye-fork length and covariance analysis were used to compare maximum body depth, depth at vent, pectoral fin length, dorsal fin height, maxillary length, snout to mandible and snout to posterior orbit lengths between sexes and areas for each species. Regression equations are given for converting fork length and mandible-fork length to eye-fork length. Based on these conversions our Pacific Ocean data on sailfish are compared with data from the Atlantic Ocean.

Length-weight regressions using both eye-fork length and fork length are given for each species by sex.

The eastern Pacific off Mexico and southern California is probably one of the world's most productive regions for billfishes. Specimens from this region, however, have too often been underrepresented in comparative studies on billfish morphology. It is the purpose of this paper to (1) present some basic data on morphometric and meristic characters of striped marlin *(Tetrapturus audax)*, blue marlin *(Makaira nigricans)*, and sailfish *(Istiophorus platypterus)* from the eastern North Pacific Ocean, and (2) discuss some sources of variation in morphometric characters.

SAMPLING

Source of Data

The data were gathered by the staff of the Tiburon Fisheries Laboratory during 1967 through 1970. The sole source of data was the sampling of sport landings at three locations. These locations were: (1) the San Diego Marlin Club at San Diego, California; (2) Rancho Buena Vista in the territory of Baja California Sur, Mexico; and (3) the Star Fleet at Mazatlán, Sinaloa, Mexico. Sampling at these locations each year was conducted primarily during the months when billfish catches were highest. The monthly distribution of samples is shown in Table 1.

The specimens examined were almost totally fish caught on one-day trips in small boats ranging from about 6 to 12 m in length. For this reason most of the samples at each location represent fishes caught in a radius of less than about 100 km from the landing site. All of the fish were kept fresh, unfrozen, and at San Diego and Buena Vista, usually moist. The billfish landed at Mazatlán tended to be in a more dried-out condition. This made full erection of the dorsal fin difficult. Many fish were, therefore, measured when the dorsal fin was only half erect, but we feel that this did not affect the results significantly. The effect of dryness on body measurements is unknown, but we feel that it was not significant. Body length measurements were made with a steel tape. Nearly all of the fish at San Diego and a few of the fish at Mazatlán were measured while hanging by the tail. Otherwise, measurements were made while fish were lying on their side on a flat surface with heads and tails raised to horizontal. We tested the effect of hanging on eye-fork lengths of 10 fish at San Diego by measuring each one while hanging

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Table 1.—Number of blue marlin, sailfish, and striped marlin sampled in 1967-70 at Buena Vista, Mazatlán, and San Diego.

	Months											
	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Blue marlin												
Buena Vista												
Female												
1967	—	—	—	—	1	—	—	—	—	—	—	1
1969	—	—	—	—	2	7	—	—	—	5	—	14
1970	—	—	—	—	—	—	—	—	15	5	—	20
Total	—	—	—	—	3	7	—	—	15	10	—	35
Mazatlán												
Female												
1969	—	—	4	6	10	2	—	—	—	—	—	22
Sailfish												
Buena Vista												
Male												
1967	—	—	—	2	—	—	—	—	—	—	—	2
1968	—	—	—	—	3	—	—	—	—	—	—	3
1969	—	—	—	—	1	3	—	—	—	5	—	9
1970	—	—	—	—	—	—	—	—	8	6	—	14
Total	—	—	—	2	4	3	—	—	8	11	—	28
Female												
1967	—	—	—	2	4	—	—	—	—	—	—	6
1968	—	—	1	3	7	7	—	—	—	—	—	18
1969	—	—	—	10	1	9	—	—	—	—	6	26
1970	—	—	—	—	—	—	—	—	—	7	14	21
Total	—	—	1	15	12	16	—	—	—	7	20	71
Mazatlán												
Male												
1967	—	—	4	5	—	—	—	—	—	—	—	9
1968	—	—	7	44	15	—	—	—	—	—	2	68
1969	1	1	25	73	142	22	—	—	—	—	—	264
Total	1	1	36	122	157	22	—	—	—	—	2	341
Female												
1967	—	—	17	11	—	—	—	—	—	—	—	28
1968	—	—	14	64	26	—	—	—	—	—	3	107
1969	4	7	17	101	93	14	—	—	—	—	—	236
Total	4	7	48	176	119	14	—	—	—	—	3	371
Striped marlin												
Buena Vista												
Male												
1967	—	—	—	53	30	—	—	—	—	—	—	83
1968	—	—	49	64	74	34	—	—	—	—	—	221
1969	—	17	86	113	39	18	—	—	—	—	—	273
1970	—	—	—	—	—	—	—	—	6	33	1	40
Total	—	17	135	230	143	52	—	—	6	33	1	617
Female												
1967	—	—	—	46	19	—	—	—	—	—	—	65
1968	—	—	37	48	60	25	—	—	—	—	—	170
1969	—	22	51	54	42	29	—	—	—	9	—	207
1970	—	—	—	—	—	—	—	—	6	32	6	44
Total	—	22	88	148	121	54	—	—	6	41	6	486

Table 1.—Number of blue marlin, sailfish, and striped marlin sampled in 1967-70 at Buena Vista, Mazatlán, and San Diego.—Continued

	Months											
	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Mazatlan												
Male												
1967	—	—	21	7	—	—	—	—	—	—	—	28
1968	—	—	50	26	1	—	—	—	—	—	1	78
1969	13	42	30	30	5	1	—	—	—	—	—	121
1970	—	—	—	—	—	—	—	—	—	—	2	2
Total	13	42	101	63	6	1	—	—	—	—	3	229
Female												
1967	—	—	15	11	—	—	—	—	—	—	—	26
1968	—	—	31	18	—	—	—	—	—	—	4	53
1969	16	48	36	29	9	3	—	—	—	—	—	141
1970	—	—	—	—	—	—	—	—	—	—	6	6
Total	16	48	82	58	9	3	—	—	—	—	10	226
San Diego												
Male												
1967	—	—	—	—	—	—	22	50	—	—	—	72
1968	—	—	—	—	—	—	1	35	33	—	—	69
1970	—	—	—	—	—	—	—	6	—	—	—	6
Total	—	—	—	—	—	—	23	91	33	—	—	147
Female												
1967	—	—	—	—	—	—	35	126	—	—	—	161
1968	—	—	—	—	—	—	6	85	32	—	—	123
1970	—	—	—	—	—	—	3	26	2	—	—	31
Total	—	—	—	—	—	—	44	237	34	—	—	315

and then again after lying flat. The fish while hanging ranged from 1 mm shorter to 7 mm longer, the average being 3 mm longer than when lying flat. The mean difference was not significant.

Definitions of Counts and Measurements

The counts and measurements used in this study are defined below. Though the terminology is not identical, many of these are the same as those recommended by Rivas (1956).

Dorsal rays—number of rays in second dorsal fin.

Anal rays—number of rays in second anal fin.

Fork length—tip of snout to posterior margin of middle caudal rays.

Mandible-fork length—tip of mandible with mouth closed to posterior margin of middle caudal rays.

Eye-fork length—posterior margin of orbit to posterior margin of middle caudal rays.

Snout to mandible—tip of snout to tip of mandible with mouth closed.

Table 2.—Frequency of dorsal and anal fin ray counts for blue marlin, sailfish and striped marlin from the eastern Pacific.

	Number of rays						
	5	6	7	8	Total	$\bar{X}$	s
Dorsal fin rays							
Blue marlin	—	13	20	—	33	6.61	0.496
Sailfish	—	24	56	—	80	6.70	0.461
Striped marlin	10	223	14	—	247	6.02	0.312
Anal fin rays							
Blue marlin	—	5	27	1	33	6.88	0.415
Sailfish	1	29	48	1	79	6.62	0.538
Striped marlin	40	195	7	—	242	5.86	0.420

Snout to eye—tip of snout to anterior margin of orbit.

Length of maxillary—tip of mandible to posterior end of maxillary bone.

Maximum body depth—base of dorsal groove to edge of pelvic groove, in the transverse plane where this measurement is maximum (usually near base of pectorals).

Depth at vent—depth of body as described above except in the transverse plane through vent.

Length of pectoral fin—from base of first pectoral fin ray to tip of longest ray with fin folded against body.

Length of pelvic fin—from base of fin rays to tip when fin is held at slight angle from body.

Dorsal fin height—from base of first dorsal fin spine to tip of anterior lobe of first dorsal fin with fin held as nearly erect as possible (see previous section).

METHODS OF ANALYSIS

Meristic Characters

Counts of second dorsal and second anal fin rays were the only meristic characters used. It was quite evident early in the study that the number of fin rays did not vary significantly with fish size, at least for sizes of fish we examined, and that the number for a species varied within a narrow range of two to four rays (Table 2). The meristic characters were therefore eliminated from any further analyses.

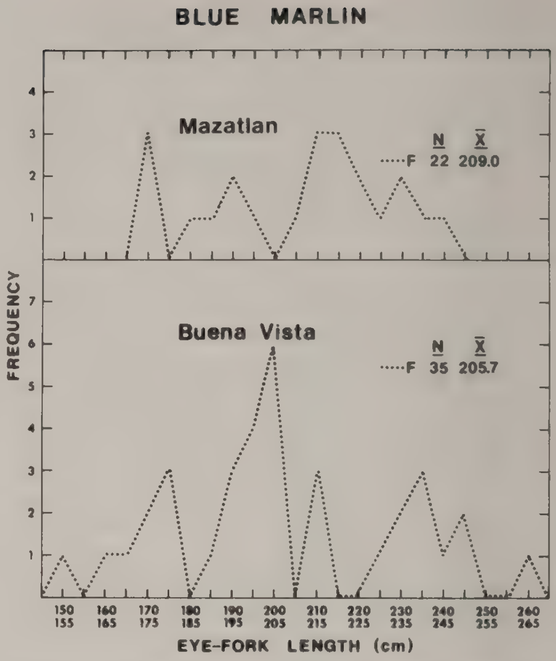

Figure 1.—Length frequency of blue marlin sampled in this study.

Morphometric Characters

Linear regression and analysis of covariance were the procedures used to analyze the data. Except for

Table 3.—Equations for converting fork and mandible-fork lengths to eye-fork length. Equations are based on $Y = a + bX$.

Relation	*a*	*b*	*N*	*r*	Range of *X* (cm)
Blue marlin					
Eye-fork length on fork length	−15.785	0.810	21	0.997	221.1-347.3
Eye-fork length on mandible-fork length	−5.105	0.893	22	0.979	194.0-297.6
Sailfish					
Eye-fork length on fork length	6.802	0.714	35	0.926	183.0-260.0
Eye-fork length on mandible-fork length	2.637	0.852	35	0.940	155.5-225.0
Fork length on eye-fork length	24.677	1.200	35	0.926	
Striped marlin					
Eye-fork length on fork length	−1.319	0.745	127	0.745	178.5-268.8
Eye-fork length on mandible-fork length	1.306	0.840	125	0.985	151.6-238.2

Table 4.—Coefficients of the weight-length relation for blue marlin, sailfish, and striped marlin from the eastern Pacific. (log weight = $a + b$ (log length)).

	Measurement						
Species	Length (cm)	Weight	a	b	Range of length (cm)	N	r
Blue marlin							
Female	Eye-fork	kg	−5.690	3.318	154.0-265.1	57	0.948
	Eye-fork	lb	−5.347	3.318	154.0-265.1	57	0.948
	Snout-fork	kg	−7.543	3.905	221.1-347.3	20	0.954
	Snout-fork	lb	−7.199	3.905	221.1-347.3	20	0.954
Sailfish							
Male	Eye-fork	kg	−4.396	2.643	115.1-196.5	367	0.867
	Eye-fork	lb	−4.057	2.643	115.1-196.5	367	0.867
	Snout-fork	kg	−5.286	2.873	183.0-260.2	24	0.910
	Snout-fork	lb	−4.946	2.873	183.0-260.2	24	0.910
Female	Eye-fork	kg	−4.084	2.507	123.1-221.7	435	0.812
	Eye-fork	lb	−3.739	2.507	123.1-221.7	435	0.812
	Snout-fork	kg	−4.059	2.356	201.7-271.0	47	0.835
	Snout-fork	lb	−3.714	2.356	201.7-271.0	47	0.835
Combined sexes	Eye-fork	kg	−4.360	2.628	115.1-221.7	802	0.846
	Eye-fork	lb	−4.017	2.628	115.1-221.7	802	0.846
	Snout-fork	kg	−4.788	2.662	183.0-271.0	71	0.890
	Snout-fork	lb	−4.446	2.662	183.0-271.0	71	0.890
Striped marlin							
Male	Eye-fork	kg	−5.005	2.999	119.6-202.6	975	0.877
	Eye-fork	lb	−4.664	2.999	119.6-202.6	975	0.877
	Snout-fork	kg	−5.166	2.903	172.0-261.0	220	0.780
	Snout-fork	lb	−4.857	2.903	172.0-261.0	220	0.780
Female	Eye-fork	kg	−5.243	3.113	110.0-215.1	1,007	0.854
	Eye-fork	lb	−4.900	3.113	110.0-215.1	1,007	0.854
	Snout-fork	kg	−5.267	2.950	153.0-271.0	315	0.778
	Snout-fork	lb	−4.914	2.950	153.0-271.0	315	0.778
Combined sexes	Eye-fork	kg	−5.157	3.071	110.0-215.1	1,982	0.864
	Eye-fork	lb	−4.816	3.071	110.0-215.1	1,982	0.864
	Snout-fork	kg	−5.340	2.982	153.0-271.0	535	0.784
	Snout-fork	lb	−5.007	2.982	153.0-271.0	535	0.784

weight-length relations, transformations of the data were not necessary because plots of the data on eye-fork length indicated that they were reasonably linear. Equations for converting fork length and mandible-fork length are given in Table 3.

The equation used in the analyses, except that for weight, was $Y = a + bX$, where Y = morphometric character measured in centimeters, and a and b = constants that are determined by least-squares procedures. For weights, the equation $\log Y = a + b \log X$, where Y = weight, X = body length, and a and b = constants, was used. Weight-length relations based on weight in kilograms and pounds and body length as eye-fork length and snout-fork length are summarized in Table 4 for blue marlin, sailfish, and striped marlin. Statistical tests were performed to test the hypotheses that the intercept of the regression, a, is zero and that the slope of the regression, b, is zero for all regressions except those for weight-length.

All plots of the data were based on averages of 5-cm groupings of eye-fork length.

BLUE MARLIN

A total of 57 blue marlin was sampled at Buena Vista and Mazatlán. The average length was 206 cm at Buena Vista and 209 cm at Mazatlán (Fig. 1).

Table 5.—Regression of morphometric character on eye-fork length (cm) for blue marlin from the eastern Pacific. Weight-length relation is based on log transformed data ($\log Y = a + b \log X$); all other relations are based on untransformed data ($Y = a + bX$). Data are for females. (* = 5% significance level; ** = 1% significance level).

Character	*a*	*b*	Range *x*	Range *Y*	*N*
Buena Vista					
Weight (kg)	−5.960	3.433	154.0-265.1	40.9-244.9	35
Maximum body depth (cm)	−5.887	0.245**	154.0-239.8	32.2- 53.6	14
Length of pectoral fin (cm)	18.594**	0.163**	154.0-265.1	40.7- 62.0	35
Length of pelvic fin (cm)	37.244**	0.003	154.0-239.8	32.1- 45.3	14
Dorsal fin height (cm)	20.966**	0.084**	154.0-265.1	31.0- 49.4	34
Length of maxillary (cm)	15.236**	0.090**	154.0-265.1	25.9- 40.2	34
Number of dorsal fin rays	6.468**	0.001	154.0-265.1	6-7	33
Number of anal fin rays	5.286	0.008**	154.0-265.1	6-8	33
Mazatlán					
Weight (kg)	−4.972	3.011	171.4-242.2	46.7-171.5	22
Length of pelvic fin (cm)	57.859**	0.096*	171.4-242.2	30.1- 45.3	22
Dorsal fin height (cm)	7.560	0.150**	171.4-242.2	32.2- 45.9	22
Length of maxillary (cm)	4.014	0.140**	171.4-242.2	26.5- 40.2	21

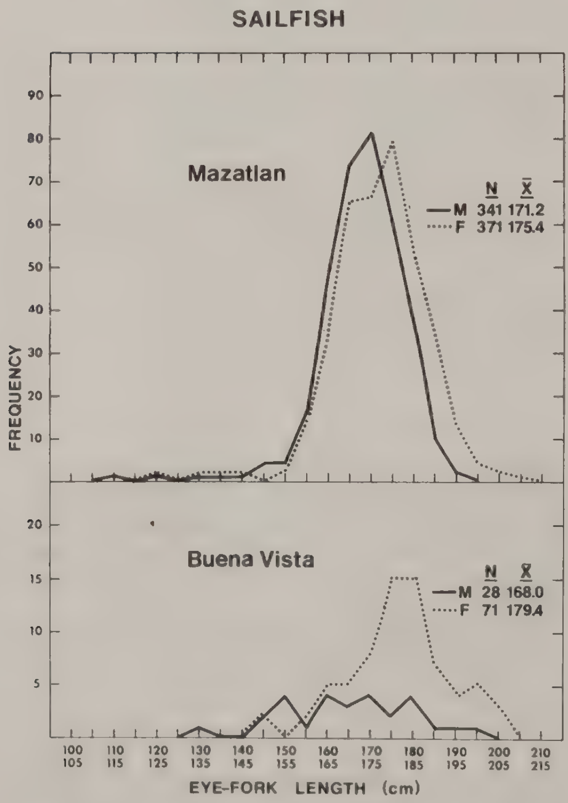

Figure 2.—Length frequency of sailfish sampled in this study.

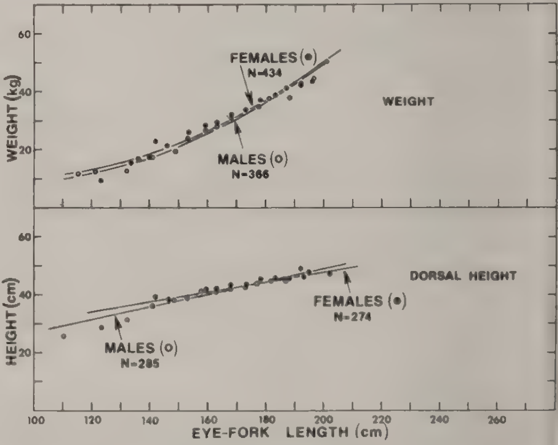

Figure 3.—Weight and dorsal height as a function of eye-fork length of sailfish from the eastern North Pacific.

Samples from both locations consisted of only females. We have no adequate explanation for this phenomenon; however, we note that in the central Pacific, which is west of our sampling area, more males than females are generally caught in the sport fishery (Strasburg, 1969). In the longline fishery sex ratios vary greatly both temporally and spatially (Kume and Joseph, 1969).

Regressions of each of the characters as a function of eye-fork length are shown in Table 5. Ex-

Table 6.—Results of analysis of covariance of morphometric character as a function of eye-fork length. The statistical test is whether the relation is significantly different among areas. (n.s. = not significant; * = 5% significance level; ** = 1% significance level).

Character	Blue marlin	Sailfish		Striped marlin	
	Female	Male	Female	Male	Female
Weight	n.s.	n.s.	n.s.	**	**
Maximum body depth	—	n.s.	*	**	**
Depth at vent	—	n.s.	n.s.	**	**
Length of pectoral fin	—	n.s.	n.s.	**	**
Length of pelvic fin	n.s.	n.s.	n.s.	n.s.	**
Snout to mandible length	—	n.s.	n.s.	**	**
Snout to eye length	—	—	*	*	**
Dorsal fin height	n.s.	n.s.	*	*	**
Length of maxillary	n.s.	n.s.	n.s.	n.s.	n.s.

cluding results for weight-length relations, results of the statistical test of $a = 0$ indicate that most of the a's are significantly different from zero. This suggests that growth of the body parts is allometric, or the parts do not grow as a constant proportion to body size, which is characteristic for most body parts of fishes (Martin. 1949).

Analysis of covariance was performed to test whether the regressions differed between sampling locations. No significant differences were found (Table 6). Samples from Buena Vista and Mazatlán were therefore pooled and the regressions were recalculated (Table 7).

SAILFISH

A total of 811 sailfish was sampled at Buena Vista and Mazatlán. Sampling at Buena Vista was in 1967-70 and at Mazatlán, only in 1967-69. More fish, however, were sampled at Mazatlán than at

Table 7.—Regression of morphometric character on eye-fork length (cm) for pooled (locations and sexes) samples of blue marlin and sailfish from the eastern Pacific. Weight-length relation is based on log transformed data ($\log Y = a + b \log X$); all other relations are based on untransformed data ($Y = a + bX$).

Character	a	b	Range of length	N
Blue marlin				
Weight (kg)	−5.690	3.318	154.0-265.1	57
Maximum body depth (cm)	−5.887	0.245	154.0-239.8	14
Length of pectoral fin (cm)	18.594	0.163	154.0-265.1	35
Length of pelvic fin (cm)	49.263	−0.056	154.0-242.2	36
Dorsal fin height (cm)	17.129	0.103	154.0-265.1	56
Length of maxillary (cm)	12.366	0.103	154.0-265.1	55
Sailfish				
Weight (kg)	−4.360	2.628	115.1-221.7	802
Maximum body depth (cm)	2.824	0.150	121.5-221.7	239
Depth at vent (cm)	10.160	0.073	121.5-221.7	239
Length of pectoral fin (cm)	0.703	0.211	121.5-221.7	279
Length of pelvic fin (cm)	12.171	0.274	115.1-203.0	529
Snout to mandible length (cm)	16.382	0.099	133.2-203.0	196
Snout to eye length (cm)	24.707	0.207	156.0-203.0	34
Dorsal fin height (cm)	8.292	0.202	115.1-203.0	559
Length of maxillary (cm)	9.910	0.110	115.1-203.0	553

Table 8.—Regression of morphometric character on eye-fork length (cm) for sailfish from the eastern Pacific. Weight-length relation is based on log transformed data ($\log Y = a + b \log X$); all other relations are based on untransformed data ($Y = a + bX$). (* = 5% significance level; ** = 1% significance level).

	Male					Female				
			Range					Range		
Character	*a*	*b*	*X*	*Y*	*N*	*a*	*b*	*X*	*Y*	*N*
Buena Vista										
Weight (kg)	−4.825	2.829	133.4-196.5	13.4-47.5	28	−4.291	2.601	146.3-203.0	20.4-54.1	70
Maximum depth (cm)	2.163	0.156**	160.9-182.9	27.8-31.3	5	14.000**	0.092**	161.5-203.0	28.6-35.0	24
Depth at vent (cm)	−11.300	0.194	160.9-182.9	19.8-26.9	5	15.743**	0.043	161.5-203.0	20.3-26.4	24
Length of pectoral fin (cm)	7.181	0.174**	133.4-196.5	27.0-44.5	21	6.997	0.181**	146.3-203.0	29.8-47.4	49
Length of pelvic fin (cm)	17.612	0.248**	152.1-182.5	54.9-64.7	8	17.844	0.239**	147.2-203.0	52.0-70.0	24
Snout to mandible length (cm)	9.092	0.131**	160.9-182.9	30.5-33.3	5	4.060	0.167*	166.0-203.0	28.0-41.3	19
Snout to eye length (cm)	—	—	—	—	—	−72.145	0.692**	187.5-203.0	56.5-68.0	4
Dorsal fin height (cm)	10.713	0.178**	133.4-196.5	30.5-50.6	22	16.723**	0.151**	146.3-203.0	37.3-51.4	46
Length of maxillary (cm)	10.609**	0.103**	133.4-196.5	23.4-32.0	21	8.903**	0.116**	146.3-203.0	23.8-32.1	46
Number of dorsal fin rays	6.316**	0.002	133.4-196.5	6-7	22	−5.446**	0.008	146.3-193.4	6-7	35
Number of anal fin rays	5.190**	0.009	133.4-196.5	6-8	21	6.350**	0.001	146.3-193.4	6-7	35
Mazatlán										
Weight (kg)	−4.291	2.594	115.1-193.5	11.7-47.2	339	−4.020	2.479	123.1-221.7	9.9-50.6	365
Maximum depth (cm)	−0.443	0.168**	121.5-190.0	19.4-34.5	77	4.196	0.141**	133.2-221.4	20.4-39.1	133
Depth at vent (cm)	8.144**	0.086**	121.5-190.0	18.2-33.9	77	10.246**	0.073**	133.2-221.7	17.9-26.8	133
Length of pectoral fin (cm)	−8.092	0.259**	121.5-190.0	20.4-43.3	77	3.954	0.192**	133.2-221.7	26.8-45.9	132
Length of pelvic fin (cm)	11.830**	0.275**	115.1-193.5	37.9-67.7	263	12.156**	0.275**	123.1-195.8	44.9-71.6	234
Snout to mandible length (cm)	14.063	0.110*	135.6-190.0	21.4-41.2	63	22.401**	0.066*	133.2-194.1	25.4-41.1	109
Snout to eye length (cm)	27.064	0.180	167.3-184.4	49.5-64.3	8	17.135	0.260**	156.0-187.1	56.0-71.0	22
Dorsal fin height (cm)	5.539	0.217**	115.1-193.5	25.5-52.4	263	11.965**	0.184**	123.1-195.8	29.1-62.8	228
Length of maxillary (cm)	8.746**	0.116**	115.1-193.5	21.1-39.1	260	12.196**	0.097**	123.1-195.8	20.8-32.3	226
Number of dorsal fin rays	7.243*	0.003	149.2-181.6	6-7	12	3.175	0.019	142.1-191.4	6-7	11
Number of anal fin rays	4.083	0.015	149.2-181.6	6-7	12	4.110	0.014	142.1-191.4	5-7	11

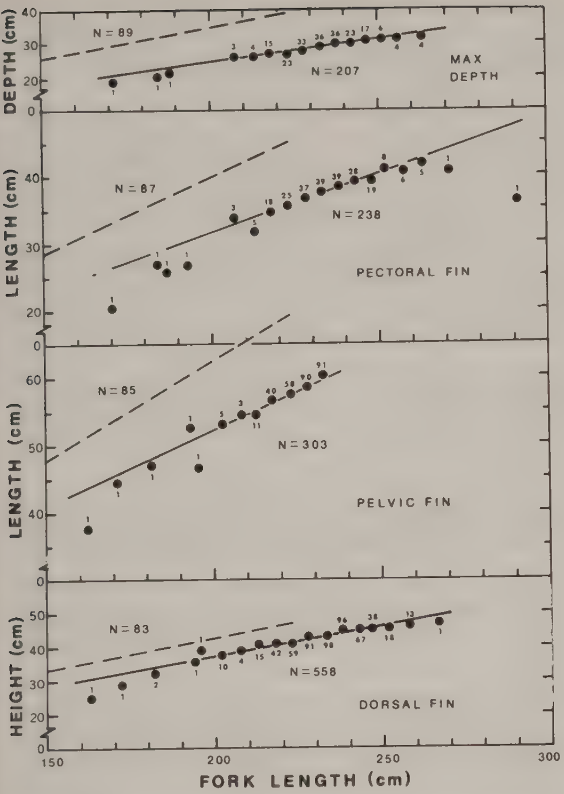

Figure 4.—Comparison of regressions of morphometric characters on fork length of sailfish from the Atlantic (dashed line) and the eastern North Pacific (solid line). Numbers indicate sample sizes for points.

Buena Vista (Table 1). At both sampling locations the sizes of sailfish were quite similar, although the females averaged 179 cm long and the males 168 cm long (Fig. 2). Between locations the size differences are statistically significant only for females.

Location and Sex Differences

Analysis of covariance was used to test whether for each sex the regressions (Table 8) were significantly different between locations (Table 6). Because there was no trend in the results, we assumed that there were no location differences and pooled the data from the two locations. We then used analysis of covariance to test whether there were differences between sexes. Only weight-length and dorsal fin height-length relations proved to be significantly different between sexes. Females were heavier for a given length than males, and females under about 160 cm long had a taller dorsal fin than males (Fig. 3). For fish larger than 160 cm long, the males had a taller dorsal fin. However, there is considerable overlap in the data for males and females, and probably the difference between sexes would disappear if a larger sample of fish were analyzed. Regressions based on the pooled data are shown in Table 7.

Comparison with Atlantic Sailfish

Morrow and Harbo (1969) analyzed meristic and morphometric measurements of sailfish from several locations in the Atlantic and Pacific Oceans. They found that the characters were similar for fish from both oceans and they therefore concluded that specimens from the two oceans belong to the same species. We used Morrow and Harbo's data from the Atlantic for comparison with our data, which provides a larger sample from the eastern Pacific

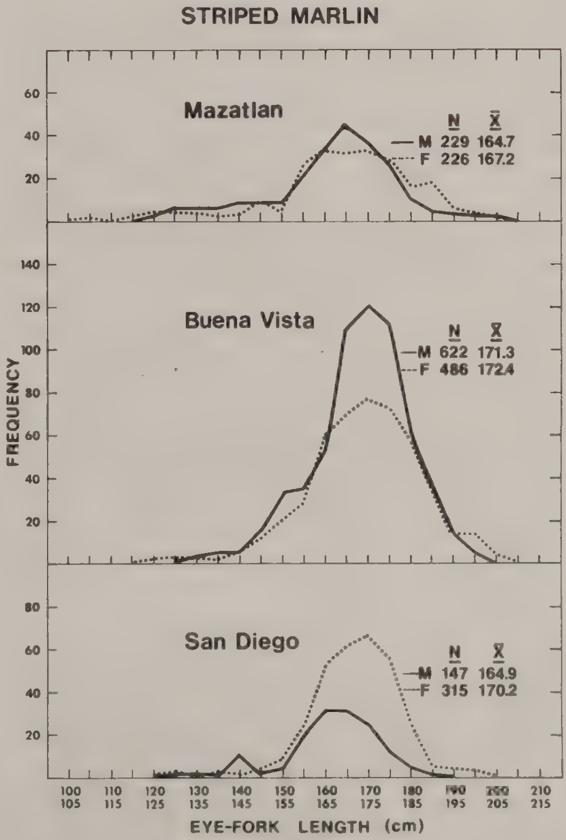

Figure 5.—Length frequency of striped marlin sampled in this study.

Table 9.—Regression of morphometric character on eye-fork length (cm) for striped marlin from the eastern Pacific. Weight-length relation is based on log transformed data ($\log Y = a + b \log X$); all other relations are based on untransformed data ($Y = a + bX$). (* = 5% significance level; ** = 1% significance level).

Character	Male					Female				
			Range					Range		
	a	*b*	*X*	*Y*	*N*	*a*	*b*	*X*	*Y*	*N*
Buena Vista										
Weight (kg)	−5.294	3.126	119.6-202.0	13.1-91.4	601	−5.420	3.183	125.0-215.1	16.9-101.3	472
Maximum depth (cm)	2.463*	0.178**	123.1-202.0	22.1-39.5	321	1.206	0.187**	125.0-215.1	22.9- 40.6	246
Depth at vent (cm)	−3.250*	0.173**	123.1-202.0	16.4-39.3	301	−1.618	0.165**	125.0-215.1	17.5- 37.8	232
Length of pectoral fin (cm)	2.557	0.242**	123.1-202.0	27.3-52.5	368	−2.124	0.273**	125.0-215.1	29.4- 59.0	303
Length of pelvic fin (cm)	41.864**	−0.041*	119.6-199.5	22.7-43.5	273	34.995**	0.006	126.9-201.4	7.5- 45.1	202
Snout to mandible length (cm)	13.376**	0.099**	123.1-202.0	15.6-41.0	280	14.324**	0.095**	125.0-215.1	22.0- 39.5	207
Snout to eye length (cm)	16.502**	0.260**	131.4-189.0	47.0-69.4	81	15.136**	0.267**	125.0-197.5	45.0- 73.0	64
Dorsal fin height (cm)	10.176**	0.171**	119.6-199.5	26.9-46.0	316	7.829	0.188	128.1-201.4	31.0- 47.2	246
Length of maxillary (cm)	5.369**	0.167**	119.6-199.5	22.9-41.3	311	5.054	0.170**	126.9-201.4	24.5- 46.2	248
Number of dorsal fin rays	6.527**	−0.003	131.0-195.2	5-7	101	5.438**	0.003	126.9-201.4	5-7	108
Number of anal fin rays	5.949	−0.001	131.0-195.2	5-7	91	5.228**	0.004	126.9-201.4	5-7	105
Mazatlán										
Weight (kg)	−5.183	3.064	120.4-202.6	15.8-73.5	227	−5.119	3.034	110.0-204.5	10.3- 86.5	222
Maximum depth (cm)	−5.508**	0.218**	124.0-200.0	20.1-36.3	104	−1.341	0.193**	116.8-204.5	22.4- 41.2	76
Depth at vent (cm)	−0.902	0.154**	124.0-200.0	16.0-29.0	104	0.588	0.144**	116.8-204.5	14.6- 32.3	76
Length of pectoral fin (cm)	−8.151**	0.302**	124.0-200.0	28.7-49.8	106	2.858	0.239**	116.8-204.5	24.0- 52.1	83
Length of pelvic fin (cm)	37.680**	0.010	120.4-202.6	21.5-44.1	118	30.045**	0.041	110.0-197.0	15.6- 45.2	136
Snout to mandible length (cm)	13.427**	0.095**	124.5-191.6	22.0-36.8	73	16.211**	0.079**	116.8-197.0	20.0- 35.2	51
Snout to eye length (cm)	7.285	0.306**	124.0-191.6	37.7-69.4	27	29.190**	0.179**	129.0-204.5	49.0- 68.0	24
Dorsal fin height (cm)	12.680**	0.155**	126.4-202.6	27.8-47.5	50	8.693*	0.180**	118.9-197.0	28.4- 48.4	61
Length of maxillary (cm)	7.467**	0.153**	120.4-202.6	22.4-38.0	107	8.380**	0.150**	118.9-197.0	25.1- 39.5	127
Number of dorsal fin rays	—	—	—	—	—	6	0	157.3-190.1	6	7
Number of anal fin rays	−1.244	0.040	170.7-180.2	5-6	3	6	0	157.3-190.1	6	7
San Diego										
Weight (kg)	−4.060	2.608	129.4-191.0	29.5-83.9	147	−4.574	2.843	127.0-203.3	22.2-103.4	313
Maximum depth (cm)	12.928**	0.120**	129.4-191.0	28.4-41.2	141	8.457**	0.153**	135.0-201.5	27.1- 46.9	284
Depth at vent (cm)	5.599**	0.129**	129.4-191.0	21.3-32.3	141	1.449	0.157**	135.0-201.5	21.0- 35.1	283
Length of pectoral fin (cm)	14.110**	0.164**	129.4-191.0	32.2-50.1	146	7.695**	0.209**	127.0-203.3	27.9- 53.2	315
Length of pelvic fin (cm)	—	—	—	—	—	—	—	—	—	—
Snout to mandible length (cm)	17.549**	0.075**	133.7-191.0	24.8-37.4	129	15.066**	0.095**	135.0-201.5	24.3- 39.8	267
Snout to eye length (cm)	27.478**	0.196**	133.7-182.7	50.4-68.1	66	19.784**	0.248**	135.0-192.5	50.6- 75.0	152
Dorsal fin height (cm)	1.095	0.207	158.2-183.0	33.6-41.0	5	2.771*	0.202**	127.0-203.3	27.5- 44.0	29
Length of maxillary (cm)	10.295	0.133	158.2-183.0	30.7-36.6	5	10.191**	0.144**	127.0-203.3	27.6- 40.1	28
Number of dorsal fin rays	—	—	—	—	—	6.272**	−0.002	127.0-203.3	5-7	31
Number of anal fin rays	8.775	−0.017	158.2-183.0	5-6	5	6.270**	−0.001	127.0-203.3	6-7	31

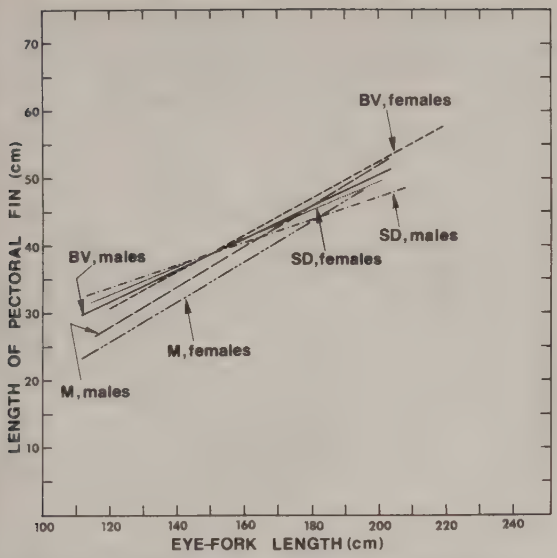

Figure 6.—Plotted regressions of pectoral fin length on eye-fork length of striped marlin by sex and locality. BV=Buena Vista, M=Mazatlán, SD=San Diego.

than was available to them (they had data on nine specimens from the coast of Peru). Body length for the Atlantic specimens was measured as fork length. In order to have the data comparable to our data, it was necessary to convert eye-fork length of our samples to fork length with the appropriate equation in Table 3.

Maximum body depth, length of pectoral fin, length of pelvic fin, and dorsal fin height were examined (Fig. 4). Analysis of covariance was not used to test for significant differences in these characters between Atlantic and eastern Pacific sailfish because of the complication of one set of data being based on converted lengths. However, we feel from visual inspection that there is sufficient separation between the regressions (especially the first three) to suggest that eastern Pacific sailfish differ significantly from Atlantic sailfish in morphometric measurements. More information based on a wide range of sizes of fish from the Atlantic and Pacific is needed for a more complete comparision.

STRIPED MARLIN

The eastern Pacific is apparently a center of high concentration of striped marlin. Considerable numbers of fish are annually caught by the commercial longline fleet and by sportsmen. In 1967-70 we sampled 2,020 specimens from the sport landings at Buena Vista, Mazatlán, and San Diego. Length frequencies of the samples are shown in Figure 5.

Location and Sex Differences

Regressions of each meristic and morphometric character as a function of eye-fork length are shown in Table 9. Analysis of covariance was performed on the data, sexes separate, to determine whether the regressions were significantly different among locations. The results (Table 6) indicated that the regressions were different. Analysis of covariance was also used to determine whether the relations were significantly different between sexes, within location. The results (Table 10) for this series of tests showed either no differences or inconsistency from one location to another, except for the relation of length of pectoral fin on eye-fork length. For this relation, significant differences between sexes were found at all three locations. The regressions are shown in Figure 6. On the basis of these results, except for pectoral fin length, it was assumed that there is no significant difference between sexes, but a significant difference among locations. The data were pooled accordingly and regressions recalculated (Table 11).

A plot of weight on eye-fork length for striped marlin from each location (Fig. 7) shows that for a given length, striped marlin from San Diego were heavier than fish from Buena Vista or Mazatlán.

Table 10.—Results of covariance analysis of morphometric character of striped marlin as a function of eye-fork length to test whether the relations are significantly different between sexes. (n.s. = not significant; * = 5% significance level; ** = 1% significance level).

Character	Buena Vista	Mazatlán	San Diego
Weight	n.s.	n.s.	n.s.
Maximum body depth	*	n.s.	**
Depth at vent	n.s.	n.s.	*
Length of pectoral fin	**	*	**
Length of pelvic fin	**	n.s.	—
Snout to mandible length	n.s.	n.s.	**
Snout to eye length	n.s.	n.s.	n.s.
Dorsal fin height	**	n.s.	n.s.
Length of maxillary	n.s.	n.s.	*

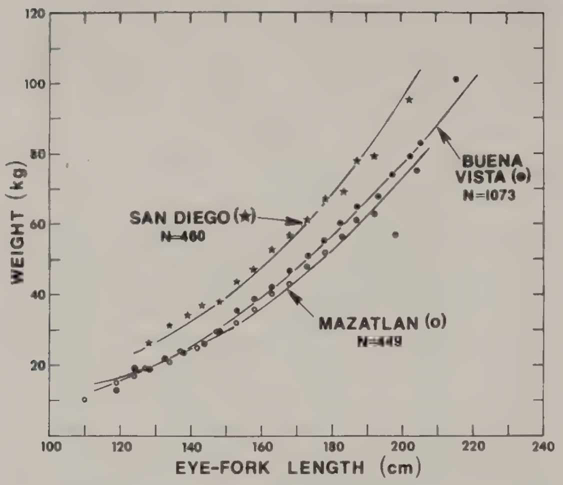

Figure 7.—Weight as a function of eye-fork length of striped marlin from the eastern North Pacific.

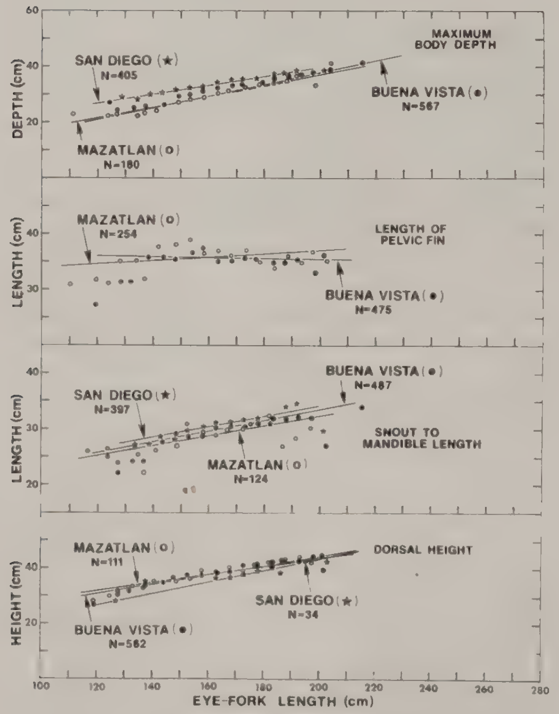

Figure 8.—Morphometric characters as a function of eye-fork length of striped marlin from the eastern North Pacific.

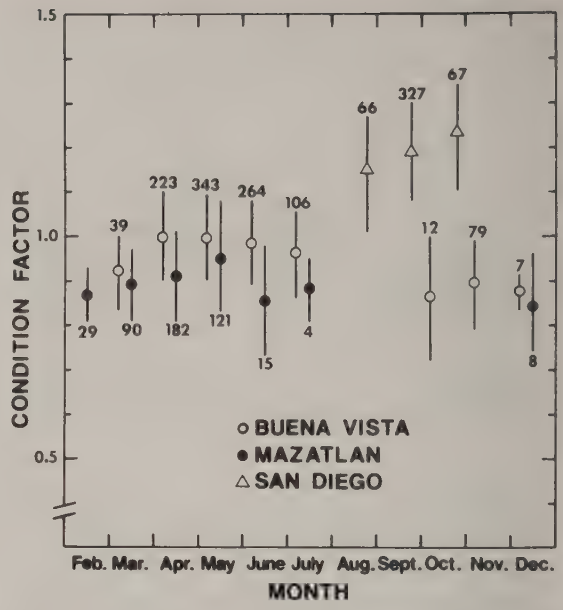

Figure 9.—Average condition factor by month for striped marlin from the eastern North Pacific. One standard deviation on each side of the mean and the sample size shown. Condition factor=$W \times 10^5/L^3$ where W=whole fish weight in kg and L=eye-fork length in cm.

This difference is also evident in the relation of maximum body depth on eye-fork length (Fig. 8); body depth is larger in San Diego fish. It was uncertain whether this difference was a seasonal phenomenon since San Diego samples were obtained only from August to October, months of the year when there were almost no samples from Buena Vista or Mazatlán (Table 1). Plots of condition factors by month for the three areas (Fig. 9), however, show that seasonal variation is unlikely to be the cause.

Some other relations are shown in Figure 8. They indicate that there is much overlap in the data. It thus appears that characters, other than perhaps weight, maximum body depth, and pectoral fin length, are not different enough to be useful as single diagnostic characters for separating striped marlin into location of capture.

Comparison with Other Studies

Kamimura and Honma (1958) examined five morphometric characters of striped marlin caught in the Pacific by the Japanese longline fleet. They dis-

Table 11.—Regression of morphometric character on eye-fork length (cm) for pooled (sexes) samples of striped marlin from the eastern Pacific. Weight-length relation is based on log transformed data ($\log Y = a + b \log X$); all other relations are based on untransformed data ($Y = a + bX$).

Character	a	b	Range of length (cm)	N
Buena Vista				
Weight (kg)	−5.356	3.154	119.6-215.1	1073
Maximum body depth (cm)	1.578	0.184	123.1-215.1	567
Depth at vent (cm)	−2.669	0.170	123.1-215.1	533
Length of pectoral fin (cm)	−0.333	0.261	123.1-215.1	671
Length of pelvic fin (cm)	38.797	−0.020	119.6-201.4	475
Snout to mandible length (cm)	13.656	0.098	123.1-215.1	487
Snout to eye length (cm)	15.750	0.264	125.0-197.5	145
Dorsal fin height (cm)	9.171	0.178	119.6-201.4	562
Length of maxillary (cm)	5.234	0.169	119.6-201.4	559
Mazatlán				
Weight (kg)	−5.143	3.045	110.0-204.5	449
Maximum body depth (cm)	−3.642	0.207	116.8-204.5	180
Depth at vent (cm)	−0.038	0.148	118.8-204.5	180
Length of pectoral fin (cm)	−3.225	0.274	116.8-204.5	189
Length of pelvic fin (cm)	33.018	0.021	110.0-202.6	254
Snout to mandible length (cm)	14.556	0.088	116.8-197.0	124
Snout to eye length (cm)	19.061	0.236	124.0-204.5	51
Dorsal fin height (cm)	10.526	0.169	118.9-202.6	111
Length of maxillary (cm)	7.840	0.152	118.9-202.6	234
San Diego				
Weight (kg)	−4.439	2.781	127.0-203.3	460
Maximum body depth (cm)	8.400	0.152	129.4-201.5	425
Depth at vent (cm)	2.245	0.152	129.4-201.5	424
Length of pectoral fin (cm)	8.262	0.204	127.0-203.3	461
Snout to mandible length (cm)	14.363	0.097	133.7-201.5	397
Snout to eye length (cm)	21.302	0.238	133.7-192.5	218
Dorsal fin height (cm)	2.534	0.203	127.0-203.3	34
Length of maxillary (cm)	10.017	0.144	127.0-203.3	33

covered that the length of the pectoral fin was significantly longer in fish caught in the South Pacific (lat. 18°-25°S) than in the North Pacific (lat. 30°-35°N). In Figure 10, we have superimposed Kamimura and Honma's equations on a band that represents the equations calculated from our data on pectoral fin lengths. The North Pacific sample is most similar to ours, which is from about lat. 20°-35°N. The South Pacific fish, on the other hand, have definitely longer pectoral fins than our samples, but only for fish less than about 210 cm long.

Data on length of pectoral fin for nine striped marlin (for which eye-fork length was available) reported by Royce (1957) from the central and eastern equatorial Pacific are also plotted in Figure 10. The plots indicate that either there is mixing in the central Pacific of the presumed South and North Pacific stocks of striped marlin or Kamimura and Honma's samples did not adequately reflect the degree of variability in length of pectoral fin of fish from the North and South Pacific.

SUMMARY AND CONCLUDING REMARKS

Morphometric data for 57 female blue marlin are presented; comparisons with fish from other areas were omitted due to the small sample size. For sailfish it appears that characters such as maximum

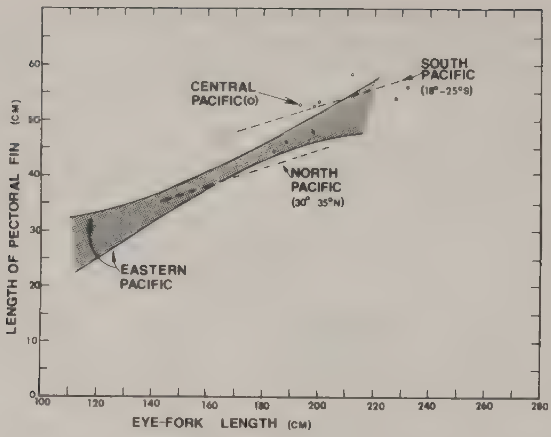

Figure 10.—Comparison of pectoral fin of striped marlin stocks in the Pacific Ocean. The shaded band represents the area in which our data for the relations of eastern Pacific fish fall. Data for South and North Pacific fish are from Kamimura and Honma (1958). Data for central Pacific fish are from Royce (1957).

body depth, length of pectoral fin, length of pelvic fin, and dorsal fin height are considerably shorter on the average in fish from the eastern Pacific than in fish of identical size from the Atlantic Ocean. For striped marlin, our results indicated that weight and maximum body depth can be used to separate striped marlin stocks within our study area. For example, a 180 cm long striped marlin landed off San Diego is, on the average, about 19% heavier and has a maximum body depth 3% greater than a striped marlin of identical size landed off Buena Vista or Mazatlán. Also, striped marlin from the northeastern Pacific (lat. 20°-35°N) and South Pacific (lat. 18°-25°S), apparently can be separated on the basis of length of pectoral fin.

We conclude, therefore, that there are morphometric characters that can be used to separate, with some degree of accuracy, sailfish and striped marlin stocks. We suggest, however, that more powerful techniques, such as multivariate analyses, be used in future attempts of stock identification of eastern Pacific billfishes.

ACKNOWLEDGMENT

We are grateful for the generous cooperation of the staff and sportsmen at Rancho Buena Vista, the Star Fleet in Mazatlán, and the San Diego Marlin Club for permitting us to measure specimens. Larry Coe, Dan Eilers. Douglas Evans, Maxwell Eldridge, and David Tolhurst helped collect the data and Brad Cowell assisted with data processing.

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Analysis of Length and Weight Data On Three Species of Billfish From the Western Atlantic Ocean

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ABSTRACT

Estimates of parameters of relations among weight, girth, total length, fork length, body length, trunk length, and caudal spread were made for blue marlin, white marlin, and sailfish captured in the western Atlantic. Some sexual differences were found.

Estimates of relations between length and weight of fish are important, because weight is often the desired measure when only length measurements are practical. For example, obtaining accurate weights on vessels at sea is difficult, especially when specimens may weigh hundreds of pounds, as is often the case for billfish. Both sport and commercial fishermen are more interested in weight than in length, for game fish records are listed by weight and commercial fishermen are paid by the weight of their catch.

Although length measurements of billfish have been taken in numerous ways (Rivas, 1956; Royce, 1957), we chose eye-fork length as the most meaningful, because it involves parts of the body that are least apt to be damaged.

In this study we estimated relations between eye-fork length and weight for blue marlin *(Makaira nigricans),* white marlin *(Tetrapturus albidus),* and sailfish *(Istiophorus platypterus)* in the western Atlantic Ocean. The relations between girth, eye-fork length, and weight were also estimated, for weight can be more accurately estimated from eye-fork length and girth than from eye-fork length alone. The relations between total length, fork length, body length, caudal spread, and eye-fork length were estimated so that measurements of the first four types could be converted to eye-fork length for comparative purposes. We also examined sexual, spatial, and temporal differences among some of the relations.

SOURCES OF DATA AND TYPES OF MEASUREMENTS

Most of the data were obtained by personnel of the Panama City Laboratory, Gulf Coastal Fisheries Center, National Marine Fisheries Service, from sportfishermen's catches in the northeastern Gulf of Mexico during 1971. Weights, lengths, girths, and sex were determined for billfishes landed at Port Eads, Louisiana, and at three ports in northwest Florida: Pensacola, Destin, and Panama City.

Data were also obtained from cooperative scientists for catches made in various years off the coasts of New Jersey, North Carolina, and Florida, around the Bahama Islands, in the Caribbean Sea, and off Rio de Janeiro.

Most measurements were made in English units, a few in metric units. All weights were recorded in pounds. Lengths were recorded in inches or in centimeters. Metric measurements were converted to inches for the analyses, since sportsmen and commercial fishermen use inches and pounds. Four kinds of length measurements plus the girth and caudal spread were made by personnel of the Panama City Laboratory, except when conditions did not permit (e.g., broken bill or shark bites). Data from the cooperating scientists consisted of one or two kinds of length plus weight.

Measurements and their criteria are listed below. Criteria for body length, girth, and caudal spread are the same as those of Rivas (1956). All, except girth, consisted of horizontal, straight-line measurements.

(1) Total length: tip of bill to line joining tips of caudal lobes.

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(2) Fork length: tip of bill to tips of mid-caudal rays.
(3) Body length: tip of lower jaw (with jaws closed) to tips of mid-caudal rays.
(4) Eye-fork length: posterior margin of eye to tips of mid-caudal rays.
(5) Caudal spread: dorsal tip to ventral tip of lobes of caudal fin.
(6) Girth: twice the curved distance along one side of the body from the pelvic groove to the dorsal edge of the dorsal groove.

METHODS OF ANALYSIS

Three equations were used in the study. The relation between $\log_{10}$ (weight) and $\log_{10}$ (eye-fork length) is given by

$$Y = A + B_1 X_1 \qquad (1)$$

where

Y = $\log_{10}$ (weight),
A = intercept,
B_1 = coefficient,
X_1 = $\log_{10}$ (eye-fork length).

The equation can be transformed to the familiar form

$$\text{weight} = A' (\text{eye-fork length})^{B_1}$$

where

$$A' = 10^A$$

by taking antilogs of both sides of (1). The relation between $\log_{10}$ (weight), $\log_{10}$ (eye-fork length), and $\log_{10}$ (girth) is given by

$$Y = A + B_1 X_1 + B_2 X_2 \qquad (2)$$

where

Y = $\log_{10}$ (weight),
A = intercept,
B_1 and B_2 = coefficients,
X_1 = $\log_{10}$ (eye-fork length),
X_2 = $\log_{10}$ (girth).

The equation can be transformed to

$$\text{weight} = A' (\text{eye-fork length})^{B_1} (\text{girth})^{B_2}$$

by taking the antilogs of both sides. The relations between eye-fork length and other measures of length are given by

$$Y = A + B_1 X_1 \qquad (3)$$

where

Y = eye-fork length,
A = intercept,
B_1 = coefficient,
X_1 = other measure of length.

Equation (1) was not used for the relation between the various measures of length because estimates of B were very close to 1, indicating that linear relations among the variables were appropriate. Equation (3) was used instead.

The parameters of (1), (2), and (3) were estimated by use of linear regressions. Analysis of covariance was used to examine sexual differences. Multivariate analysis was used to determine if white marlin could be sexed or allocated to either Florida or Louisiana given measures of length and weight.

RESULTS AND DISCUSSION

Estimates of the parameters of (1), (2), and (3) are shown in Table 1. All estimates of the parameters are significantly different from 0 at the 0.01 level of significance.

Analyses of covariance revealed no significant differences between sexes in the relations between weight and eye-fork length, between eye-fork length and the three other measures of length, and between eye-fork length and caudal spread for blue marlin. However, sexual differences were found in the relations between weight and eye-fork length and between eye-fork length and caudal spread for white marlin (Fig. 1 and 2). Female white marlin tend to weigh more at a given length than male white marlin, but this difference tends to disappear at larger sizes. Further examination of the data indicates that the difference is partially the result of females tending to have deeper bodies than males. Male white marlin tend to have a wider caudal spread than females and the difference tends to increase with size. A sexual difference in caudal spread was also found for sailfish (Fig. 3), but the difference decreases with increased size. Sexual differences were not found in the length-weight relation for sailfish.

Deviations from the length-weight relation of the

Table 1.—Estimates of parameters of equations (1), (2), and (3).

Species	Y[1]	X_1[1]	X_2[1]	A	B_1	B_2	Sample size	Standard error	Range of X_1 (inches)	
									Minimum	Maximum
Blue marlin	W	LL4	—	-3.84620	3.28222	—	78	0.0566	50.8	103.5
Blue marlin	W	LL4	G	-3.15120	1.80496	1.27853	78	0.0390	50.8	103.5
Blue marlin	L4	L1	—	1.68522	0.66670	—	80	1.9740	73.0	149.0
Blue marlin	L4	L2	—	3.07821	0.72374	—	80	1.6853	64.0	134.0
Blue marlin	L4	L3	—	-0.74597	0.88352	—	83	2.1451	58.0	117.0
Blue marlin	L4	TT	—	4.33691	1.93860	—	75	5.1410	24.0	48.0
White marlin	W	LL4	—	-2.41011	2.37515	—	182	0.0593	47.5	70.0
White marlin	W	LL4	G	-2.20239	1.24968	1.25290	177	0.0472	47.5	70.0
White marlin	L4	L1	—	-0.71780	0.66084	—	196	1.8680	72.5	99.0
White marlin	L4	L2	—	-0.59179	0.73942	—	193	1.5571	65.5	91.0
White marlin	L4	L3	—	1.17904	0.83010	—	192	1.1205	56.0	79.0
White marlin	L4	TT	—	40.38790	0.64258	—	185	3.0604	11.0	27.0
Sailfish	W	LL4	—	-3.89480	3.15757	—	244	0.0532	15.8	62.5
Sailfish	W	LL4	G	-3.36702	2.27782	0.73757	242	0.0480	15.8	62.5
Sailfish	L4	L1	—	-1.96822	0.68216	—	260	1.5403	26.0	93.0
Sailfish	L4	L2	—	-1.09314	0.75088	—	260	1.2235	23.0	85.0
Sailfish	L4	L3	—	-0.78628	0.87262	—	267	0.9175	19.2	72.5
Sailfish	L4	TT	—	11.66889	1.87509	—	256	4.0575	4.0	28.0

[1] W = $\log_{10}$(weight)
LL4 = $\log_{10}$(eye-fork length)
L4 = eye-fork length
L1 = total length
L2 = fork length
L3 = body length
TT = caudal spread
G = girth

three species were plotted against month of capture to examine the possibility of seasonal patterns in the relations. None was found.

Multivariate analysis was used in an attempt to develop a method of sexing white marlin given weight, caudal spread, and the measures of length. Approximately 75% of the specimens could be properly sexed. Although this procedure produced better results than pure guesswork, the results are not satisfactory for scientific purposes.

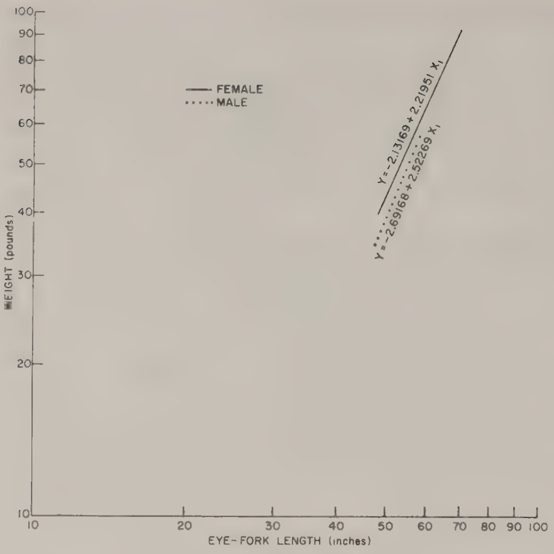

Figure 1.—Relationship of weight and eye-fork length of white marlin *(Tetrapturus albidus)* by sex.

Multivariate analysis was also used to determine if white marlin could be allocated to Florida or Louisiana given weight, caudal spread, and the measures of length. White marlin could not be so allocated.

A review of the literature revealed that very little had been done on length-weight relations of billfishes in the western Atlantic Ocean. De Sylva and Davis (1963) estimated the relation between body length and weight for white marlin and noted the same sexual difference found in this study. De Sylva (1957) plotted weight and total lengths of sailfish but did not estimate the parameters of the relation.

The results of our analyses will permit conversions from one type of length to another and also will provide better estimates of weight from length plus girth measurements.

ACKNOWLEDGMENTS

Many people aided in establishing our sampling stations in the Gulf of Mexico and in obtaining the data. These include G. Maddox, L. Ogren, J. Yurt, R. Metcalfe, J. Ogle, J. Lockfaw, and R. Schwartz. Cooperative scientists who provided data from their files were D. Erdman, L. Rivas, J. Casey, and F. Mather, III. Officers and members of the New Orleans Big Game Fishing Club, Mobile Big Game Fishing Club, Pensacola Big Game Fishing Club, Destin Charter Boat Association, and the Panama City Charter Boat Association were extremely cooperative. To all of these people, we owe a debt of gratitude. And finally, we thank all the cooperative boat captains and anglers for allowing us to examine their catches.

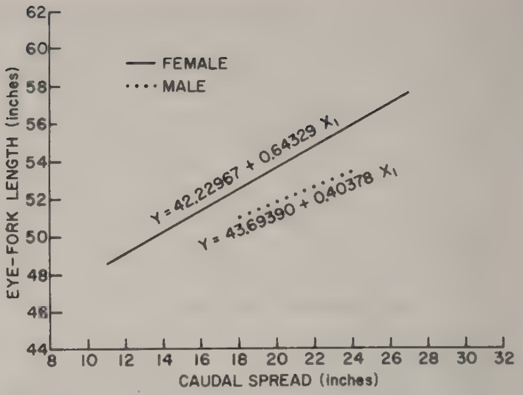

Figure 2.—Relationship of eye-fork length and caudal spread of white marlin *(Tetrapturus albidus)* by sex.

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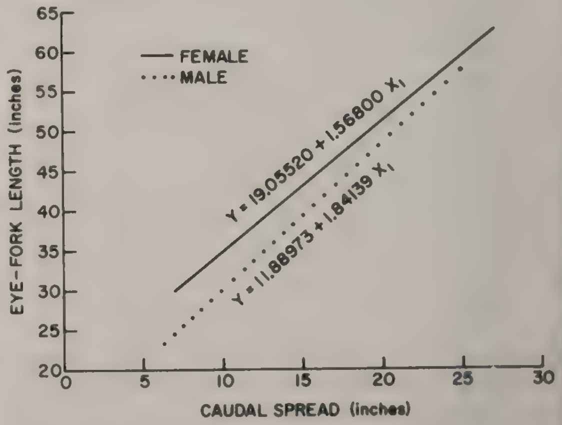

Figure 3.—Relationship of eye-fork length and caudal spread of sailfish *(Istiophorus platypterus)* by sex.

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Length-Weight Relationships for Six Species of Billfishes in the Central Pacific Ocean

ROBERT A. SKILLMAN and MARIAN Y.Y. YONG[1]

ABSTRACT

Weight-length relationships for six species of billfishes in the central Pacific Ocean were developed by analyzing 20 yr of data. Log-linear and nonlinear statistical models were fitted to the data by regression analysis, and residuals from the models were tested. Blue marlin, *Makaira nigricans* Lacépède, (50-135 cm FL), male blue marlin (≥135 cm FL) and sailfish, *Istiophorus platypterus* (Shaw and Nodder), apparently have coefficients of allometry less than 3.0. Black marlin, *M. indica* (Cuvier) and female blue marlin (≥135 cm FL) apparently have coefficients equal to 3.0. Shortbill spearfish, *Tetrapturus angustirostris* Tanaka, striped marlin, *T. audax* (Philippi), and swordfish, *Xiphias gladius* Linnaeus, apparently have coefficients greater than 3.0.

As with most studies on the length-weight relationship, this study is not an end in itself. It was initiated to provide length-weight conversion relationships (Equation 1) for use in a growth paper on blue and striped marlins (Skillman and Yong[2]), as well as to provide conversion charts for the sport fishermen at the Hawaiian International Billfish Tournament. There are few published papers on the weight-length relationship of billfishes[3] (de Sylva, 1957; Royce, 1957; Kume and Joseph, 1969); hence, we decided to calculate this relationship for all six species of billfishes on which data had been collected by the Honolulu Laboratory of the Southwest Fisheries Center, National Marine Fisheries Service. These six species were the black marlin, *Makaira indica* (Cuvier), blue marlin, *M. nigricans* Lacépède, sailfish, *Istiophorus platypterus* (Shaw and Nodder), shortbill spearfish, *Tetrapturus angustirostris* Tanaka, striped marlin, *T. audax* (Philippi), and swordfish, *Xiphias gladius* Linnaeus.

Although all of the length-weight data collected on billfishes from 1950 to 1971 by the Honolulu Laboratory were used, this study should not be considered exhaustive or definitive. Even in the best represented species, there were too few data to separate the data according to sex, maturity, and season as suggested by Le Cren (1951) and Tesch (1968). Thus, it was impossible to perform a detailed analysis of covariance similar to that performed recently by Brown and Hennemuth (1971) on haddock, *Melanogrammus aeglefinus* (Linnaeus). Some species were so poorly represented that the length-weight relationships should be considered as tentative relationships.

In general, fishery biologists have accepted the appropriateness of the allometric growth equation (Huxley and Teissier, 1936) or its mathematical equivalent, the power function, as a descriptor of growth in weight to growth in length. We accepted the general form of the relationship (Equation 1) and applied both the log-linear and the nonlinear statistical

$$W_i = b_1 L_i^{a_1} \qquad (1)$$

models of the relationship. Each model is discussed, and statistical procedures for evaluating the goodness of fit are presented. Papers by Glass (1969), Pienaar and Thomson (1969), and Hafley (1969) are particularly relevant to this discussion.

MATERIALS AND METHODS

Collection of Data

The data used in this report came from three sources. In nearly all of them fork length (FL) measurements were taken to the nearest centimeter from the tip of the snout to the fork of the tail. Where naris or eye-orbit fork length measures were given, conversion to FL was performed with equations given by Royce (1957). All weight measurements were taken to the nearest pound and were converted to kilograms before analysis.

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[1] Southwest Fisheries Center, Honolulu Laboratory, National Marine Fisheries Service, NOAA, Honolulu, HI 96812.

[2] Skillman, R.A., and M.Y.Y. Yong. Growth of blue marlin, *Makaira nigricans* Lacépède, and striped marlin, *Tetrapturus audax* (Philippi) in the north central Pacific Ocean by the progression of modes method. Manuscript. National Marine Fisheries Service, Southwest Fisheries Center, Honolulu, HI 96812.

[3] The term billfishes, as used in this paper, includes swordfish.

Two of the data sets were derived from longline catch records taken by research vessels of the Honolulu Laboratory while fishing in central Pacific waters, mostly near the equator. The first of these data sets (deck 1) was obtained from a morphometric study of billfishes by Royce (1957) that was carried out on a series of longline cruises in 1950 to 1953. The second data set (deck 2) was obtained from routine information collected from longline-caught fishes for the years 1950 to 1971. These two longline data sets were combined in the subsequent analyses because they represent the same type of data, though they were collected for different reasons and, in general, do not overlap in time. The last set of data (deck 3) was collected by personnel of the Honolulu Laboratory from fish caught by trolling between 1962 and 1971, in June (once), July, or August during the Hawaiian International Billfish Tournament held in Kailua-Kona, Hawaii (Table 1). Since the five species other than blue marlin were represented in such small numbers in the sample, they were pooled with the longline data. For blue marlin, the trolling-derived data were analyzed separately from the longline-derived data. The longline data represent a pooling over all seasons of oceanic-caught fish while the trolling data represent only inshore catches during the summer months.

All three data sets for most species contained some determinations of sex and maturity, but only the trolling data (deck 3) for blue marlin contained enough information to allow an examination of the sexes separately. All other species and pooled data sets were examined without regard to the sex of the individuals.

Analysis

The goal of this paper was to obtain length-weight relationships for each species by using a statistical model that fitted the data best. To accomplish this goal, the steps listed below were followed:

1. The data were checked for different growth stanzas by plotting the natural logarithms of weight against the natural logarithms of length.
2. Length-weight relationships using log-linear regression for weight on length were obtained for all species.
3. The normality of the error terms was tested for those species that had enough data to perform the tests.
4. The log-linear relationships were tested for their significance.
5. Length-weight relationships using nonlinear regression of weight on length were obtained for blue and striped marlins.
6. Statistical tests were performed to determine whether the log-linear or the nonlinear model was more appropriate.
7. The coefficients of allometry were tested to see if they were different from 3.0.

In subsequent paragraphs, brief discussions will be given regarding adjustments made for the amount of data available for each species, the statistical models themselves, the criteria used to determine best fit, and certain test statistics employed in the analysis.

As can be seen from Table 1, the amount of data available for most of the species for any data deck was very small. Even after pooling all of the data for the black marlin, sailfish, shortbill spearfish, and swordfish, there were too few data to evaluate the fit of the statistical models. Hence, the most commonly used statistical model, the log-linear, was fitted to these species. Only the significance of the relationships was tested. For striped marlin after pooling all data, there were enough data to evaluate the fit of the statistical models. In the analysis of blue marlin, the data were not pooled because we believed that the longline- and troll-derived data represented different biological situations. The longline data were obtained from a sampling program that neglected any seasonally varying and sexually different length-weight relationships, whereas the troll data were obtained in the summer season for each sex. To aid in the interpretation of the striped marlin data, the blue marlin data were pooled for comparative purposes only. There were enough data to evaluate the fit of the models for all blue marlin data categories.

As mentioned in the introduction of this paper, fishery biologists, in general, have accepted the appropriateness of the allometric growth equation as a descriptor of the growth in weight to the growth in length of fish. As expressed by Equation 1, this equation is mathematically a functional relationship (Madansky, 1959) where weight is known exactly

Table 1.—Number of observations by species, by year, by data deck, where deck 1 is from Royce (1957), deck 2 is the Honolulu Laboratory's longline punch card deck, and deck 3 is from the Hawaiian International Billfish Tournament.

	Year																						
Species	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	Total
Black marlin																							
Deck 1	—	—	—	4	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	7
Deck 2	—	—	—	—	3	2	3	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	9
Deck 3	—	—	—	—	—	—	—	—	—	—	—	—	1	2	—	—	2	—	2	1	—	—	8
Pooled 1, 2, 3	—	—	—	4	6	2	3	—	—	—	—	—	1	2	—	—	3	—	2	1	—	—	24
Blue marlin																							
Deck 1	—	—	8	19	8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	35
Deck 2	—	—	4	17	12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	35
Deck 3	—	—	—	—	—	—	—	—	—	—	—	—	23	17	29	45	24	63	34	31	85	34	385
Pooled 1, 2	—	—	12	36	20	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	70
Sailfish																							
Deck 1	—	—	1	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
Deck 2	—	—	1	7	3	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	13
Deck 3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	2
Pooled 1, 2, 3	—	—	2	7	5	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—	2	—	18
Shortbill spearfish																							
Deck 1	—	—	2	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5
Deck 2	—	—	1	2	—	1	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	10
Deck 3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
Pooled 1, 2, 3	—	—	3	5	—	1	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	16
Striped marlin																							
Deck 1	—	—	5	2	7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	14
Deck 2	1	—	1	1	4	—	5	—	—	—	1	—	—	1	—	—	2	12	—	—	—	—	28
Deck 3	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	2	1	4	—	2	—	11
Pooled 1, 2, 3	1	—	6	3	11	—	5	—	—	—	1	—	—	2	1	—	4	13	4	—	2	—	53
Swordfish																							
Deck 1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Deck 2	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	6	—	—	—	—	7
Deck 3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pooled	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	6	—	—	—	—	7
Total	1	—	23	56	42	4	14	—	—	—	2	—	24	21	30	45	31	82	40	32	91	35	573

from a given length; this is not a biologically reasonable model. Traditionally, length has been viewed as the independent variable that is measured with no error and weight as the random dependent variable that is measured with error. The validity of these assumptions is beyond the scope of this paper and will not be discussed. We have concerned ourselves with the appropriateness of two statistical models, the log-linear and nonlinear models. The log-linear model, with log-additive error, was written as

$$\ln W_i = \ln b_2 + a_2 \ln L_i + \ln \epsilon_{2i}. \qquad (2)$$

The arithmetic equivalent of this model can be written as

$$W_i = b_2 L_i^{a_2} \epsilon_{2i},$$

but this equation should not be construed to be the model. The nonlinear model, with additive error, was written as

$$W_i = b_3 L_i^{a_3} + \epsilon_{3i}. \qquad (3)$$

The evaluation of the goodness of fit of regression lines can be divided into distinct tests of precision (or significance) of the regression and of the appropriateness of the model. The appropriateness of a model (Equation 2 or 3) was tentatively accepted, and the model was fitted to the data. The precision of this fit can then be measured by the "*F*" test and the "*t*" test, both of which test H_N: $a = 0$ and H_A: $a \neq 0$, or the "R^2" statistic, the "proportion of total variation about the mean $\bar{Y}$ [$\bar{W}$] explained by regression" (Draper and Smith, 1966). All of these tests are equivalent and basically measure the usefulness of the regression as a predictor. To be able to perform any of these tests, the random error term must be normally distributed. The distribution of $\epsilon'_{2i} = \ln \epsilon_{2i}$ was tested for the log-linear model by calculating R.A. Fisher's statistics for skewness (G1) and kurtosis (G2, measuring the amount of peakness or bimodality). A model can fail in the significance tests because the model is incorrect or because the sample size is small relative to the amount of variability in the data. In addition, if a model is nonlinear in its parameters, it is not possible to test for significance because the variance estimates are biased, making it superfluous to test the distribution of the error term, ϵ_{3i}. Moreover, the residual sums of squares for linear and nonlinear least squares fitting routines cannot be compared because they are minimal estimates in their respective sample spaces. We chose to present the "R^2" and "*F*" statistics for the log-linear model as an indication of precision, but did not use the statistics in deciding best fit, since they cannot be compared to those obtained for the nonlinear model.

Our criteria for best fit of the models were based on measures of appropriateness, namely, whether the error terms have the following properties:

[4]
$$\begin{aligned} E[\epsilon'_{2i}] &= 0 \text{ or } E[\epsilon_{3i}] = 0 \\ \mathrm{Var}(\epsilon'_{2i}) &= \sigma_2^2 \text{ or } \mathrm{Var}(\epsilon_{3i}) = \sigma_3^2, \end{aligned} \qquad (4)$$

that is, the error terms have a mean equal to zero and a constant variance. The error terms for the log-linear model must have a mean equal to zero, since an intercept term was included in the model (Draper and Smith, 1966, p. 87). For the nonlinear model, it is not readily apparent that the error term must be equal to zero; hence, the mean was calculated. The residuals were plotted against the dependent and independent variables to check for constant variance. If variance is constant, the residuals appear as a horizontal band along the variable axes (Draper and Smith, 1966, p. 86).

The final regression coefficients, or coefficients of allometry, were tested using the hypothesis scheme H_N: $a = 3.0$, H_A: $a \neq 3.0$ (Steel and Torrie, 1960, p. 171).

In reporting the results of the various statistical tests, the following convention was used: "NS" indicates not significant at the 0.05 level, "*, **, ***" indicate significance at the 0.05, 0.01, 0.001 levels, respectively; and "*d.f.*" stands for degrees of freedom.

RESULTS

Growth Stanzas

The weight-length data for each species were first plotted with logarithms of weight versus logarithms of fork length in order to subjectively check for more than one growth stanza (Tesch, 1968). Blue marlin

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[4] From this statement, the estimated value of the log-error term, ϵ'_{2i}, may be taken as zero which in turn indicates that $\hat{\epsilon}_{2i}$ in the arithmetic equivalent to the log-linear model (Equation 2) may be taken as equal to one. If the arithmetic equivalent to the log-linear model were designated as a separate model, it does not follow that $E\,[\epsilon_{2i}] = 1$ or that $\mathrm{Var}(\epsilon_{2i}) = \sigma_2^2$.

Table 2.—Weight-length relationships for billfishes using the log-linear model (Equation 2). The pooled category under the data set heading indicates pooling of longline and trolling data. Dashes indicate that statistical tests were not appropriate. The pooled data for blue marlin includes trolling-derived data for which sex was not determined.

Species	Data set	Sample size (*N*)	*b*	*a*	R^2 in percent	Variance			G1[1]	G2[1]	*F*[1]
						ln*W*.ln*L*	*a*	*b*			
Black marlin	Pooled	24	2.3787×10^{-6}	3.1654	97.2	0.0069	0.0131	0.4134	—	—	766.36***
Blue marlin 50-135 cm FL	Longline	4	5.1827×10^{-1}	0.6678	96.4	0.0072	0.0084	0.1654	—	—	52.93*
Blue marlin ≥135 cm FL	Pooled	[2]453	5.0048×10^{-6}	3.0214	95.0	0.0126	0.0326	0.0011	−0.29**	1.77**	—
	Longline	68	4.7226×10^{-6}	3.0442	96.2	0.0172	0.0055	0.1672	0.15 NS	—	1,677.27***
	Trolling	[2]385	5.0811×10^{-6}	3.0165	94.7	0.0116	0.0013	0.0406	−0.58**	2.09**	—
	Trolling	384	4.2968×10^{-6}	3.0470	94.9	0.0111	0.0013	0.0404	−0.48**	1.88**	—
	Trolling (male)	276	2.2929×10^{-5}	2.7405	82.7	0.0118	0.0057	0.1719	−0.72**	2.62*	—
	Trolling (female)	[2]86	3.9820×10^{-6}	3.0611	92.0	0.0153	0.0096	0.3171	−0.73**	1.95*	—
	Trolling (female)	85	1.9445×10^{-6}	3.1871	93.2	0.0127	0.0089	0.2914	−0.12 NS	−0.29 NS	1,144.57***
Sailfish	Pooled	18	2.0739×10^{-5}	2.6054	84.8	0.0228	0.0762	2.1770	—	—	89.04***
Shortbill spearfish	Pooled	16	5.0083×10^{-8}	3.8338	65.2	0.0332	0.5596	14.3795	—	—	26.27***
Striped marlin	Pooled	53	5.7126×10^{-7}	3.3756	93.1	0.0336	0.0166	0.4723	1.14**	—	—
Swordfish	Pooled	7	2.3296×10^{-7}	3.5305	98.9	0.0169	0.0286	0.8401	—	—	435.34***

[1] *** indicates significance at the 0.001 level, ** indicates significance at the 0.01 level, NS indicates not significant at the 0.05 level, * indicates significance at the 0.05 level.

[2] These data sets include the same single aberrant datum.

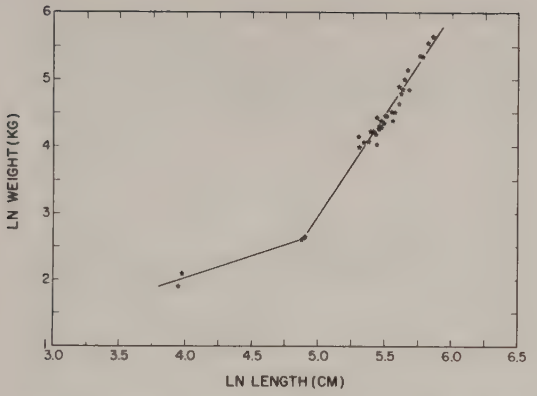

Figure 1.—Blue marlin data from longline data are plotted on a log-log scale to show the existence of two growth stanzas. The straight lines were fitted by eye.

was the only species exhibiting such a trend (Fig. 1) and then only for the longline-caught fish. Although it was quite evident that two growth stanzas existed, there were too few data to determine exactly where the two stanzas met or overlapped. We arbitrarily took the two data points at 135 cm FL (4.9 in natural logarithms) as the overlap area, with the assumption that the length-weight relationship for the older, well-represented stanza should be accurately predicted even if it actually began at a smaller size while that for the younger stanza is provisional. The younger growth stanza was treated separately in the subsequent analyses.

Log-Linear Model

The log-linear model (Equation 2) was fitted to the data for all species (Table 2). The *"F"* tests for black marlin, sailfish, shortbill spearfish, and swordfish were highly significant. Though the idea that a log-linear relationship between weight and fork length might not exist was rejected, this was a provisional conclusion because the validity of the statistical tests could not be checked. The proportion of the total variation accounted for by the regression, R^2, was high for all species except for the shortbill spearfish, where the usefulness of the relationship as a predictor was not great. For striped marlin, although the "R^2" value was high, the distribution of the error term was not normal. The sample size was too small to evaluate kurtosis, but since the more critical condition of skewness was highly significant, tests of significance could not be performed. For comparative purposes, the log-linear model was fitted to the pooled data for the blue marlin, and, as was the case for striped marlin, the error term was not normally distributed. For the blue marlin longline data, the error term was not skewed, and there were too few data to test for kurtosis. Tentatively accepting the error term as being normally distributed, the *"F"* test showed that the regression was highly significant. For the trolling data, the error term was not normally distributed; hence, tests of significance could not be performed. Examination of the error terms showed that there was one aberrant datum;

Table 3.—Weight-length relationships for blue and striped marlins using the nonlinear model (Equation 3). The data sets pooled category indicates pooling of longline and trolling data.

Species	Data set	Sample size (*N*)	*b*	*a*	R^2 in percent	$\bar{\epsilon}$	G1[1]	G2[1]
Blue marlin ≥135 cm FL	Pooled	453	6.3087×10^{-6}	2.9827	93.1	−0.5717	—	—
	Longline	68	3.9290×10^{-6}	3.0821	94.4	−1.1889	—	—
	Trolling	385	8.5300×10^{-6}	2.9265	92.2	−0.6549	−2.299**	36.691**
	Trolling	384	1.9421×10^{-6}	3.1895	98.9	0.3003	−0.266*	3.723**
	Trolling (male)	276	18.9972×10^{-6}	2.7756	83.1	0.1438	0.121 NS	2.894**
	Trolling (female)	86	4.8246×10^{-6}	3.0249	90.8	0.4055	−2.991**	20.499**
	Trolling	85	1.7082×10^{-6}	3.2111	91.9	−0.1341	−0.067 NS	0.577 NS
Striped marlin	Pooled	53	1.0978×10^{-6}	3.2589	90.7	−0.1553	—	—

[1] ** indicates significance at the 0.01 level, * indicates significance at the 0.05 level, and NS indicates not significant at the 0.05 level.

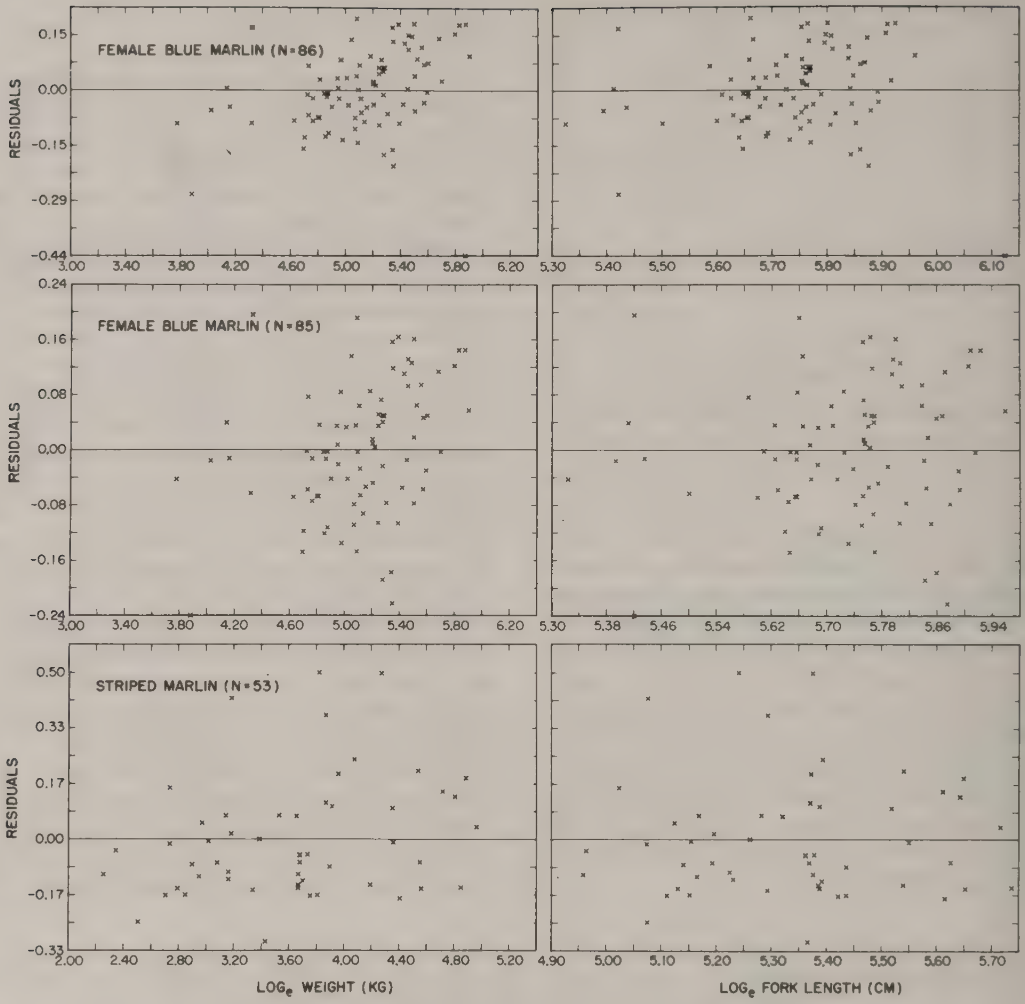

Figure 2.—Plot of residuals from the log-linear model for female blue marlin with 86 and 85 samples and for striped marlin with 53 samples. Weight was recorded in kilograms and fork length in centimeters.

however, the elimination of this datum did not alter the results significantly. When the trolling data were divided into males and females, the error terms were still not normally distributed. However, when the above mentioned aberrant datum for the female data was dropped from the calculations, the error terms were normally distributed. The "*F*" test showed that the relationship was highly significant, and the relationship accounted for 93% of the variation in the data.

For large blue marlin (five relationships) and striped marlin, the residuals about the regression line were plotted against the dependent (weight) and independent (fork length) variables in order to evaluate the fit of the log-linear model. In every case, the distribution of the residuals appeared as a band along the axes; hence, the model appeared to fit the data. The results for striped marlin and blue marlin (trolling data for females with all data points and with the one aberrant datum point dropped) were representative of all the species plots. These results are presented in Figure 2. The two plots for the blue marlin indicated the effect of the aberrant datum that was discussed earlier when the normality of the residuals was tested. In spite of the residuals not being normally distributed for all except two of

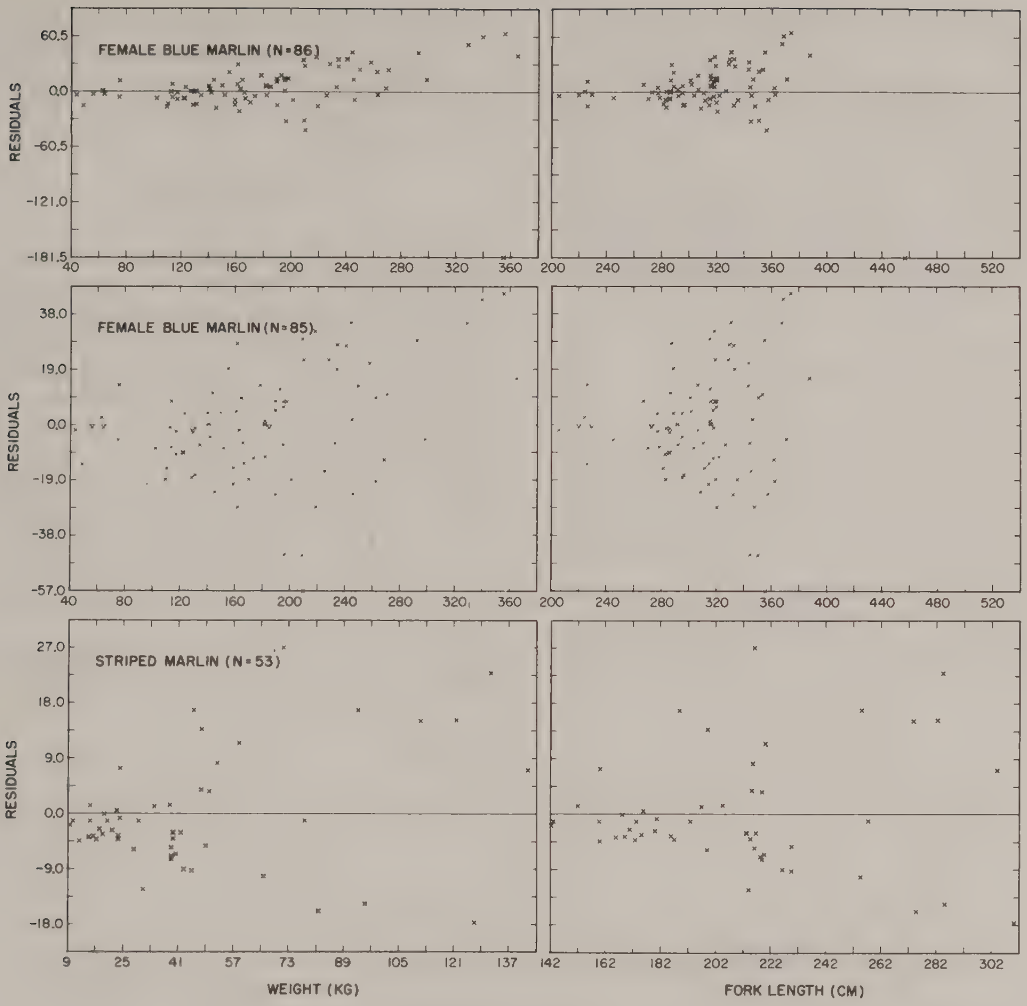

Figure 3.—Plot of residuals from the nonlinear model for female blue marlin with 86 and 85 samples and for striped marlin with 53 samples.

the cases (Table 2), the plotting of the residuals indicated that there was no reason to reject the assumption of constant variance. Hence, the log-linear model seemed to be appropriate.

Nonlinear Model

The nonlinear model (Equation 3) was fitted to the data for the large blue marlin (five relationships) and the striped marlin (Table 3) in order to compare the fit of this model to that for the log-linear model. Since the estimate of σ^2 is biased in nonlinear regression and therefore tests of significance cannot be made, the distribution of the error terms was not tested. The estimates of "R^2" (a biased estimator in this nonlinear case) indicated that the nonlinear model does not in general account for as much of the variation in the data and is, therefore, not as good a predictor as the log-linear model. When the residuals from the nonlinear regression lines were plotted against the dependent and independent variables, it was found in every case that the amount of error was small for small values of the variables and large for large values of the variables. Hence, the assumption of constant variance of the error term must be rejected for all cases. The results for blue marlin, trolling data for females with 86 and 85 data points, and for striped marlin presented in Figure 3 were representative of all species plots. Comparing these plots with those in Figure 2 showed that the nonlinear model did not fit the data as well as did the log-linear model. Since both assumptions regarding the properties of the error terms were rejected, it must be concluded that the nonlinear model is not appropriate for these sets of data.

Coefficients of Allometry

The coefficients of allometry that will be discussed in this section were obtained from the fitting of the log-linear model. For those species and data sets in Table 2 where the assumption of normality of the residuals was rejected, the coefficients of allometry were not tested. The hypotheses tested were H_N: $a = 3.0$ and H_A: $a \neq 3.0$ (a two-sided "t" test), and the results of these tests are presented in Table 4. For small blue marlin and swordfish, the null hypothesis that $a = 3.0$ was rejected on the basis of the data available. For black marlin, large blue marlin (longline data), female blue marlin, sailfish, and shortbill spearfish, the alternate hypothesis that $a \neq 3.0$ was rejected on the basis of the data available.

DISCUSSION

Weight-length relationships were fitted successfully for all six species of billfishes appearing in the Honolulu Laboratory's collections (Figs. 4 and 5). The log-linear relationships (Table 2) were found to be more appropriate than the nonlinear relationships (Table 3) for every species and data set. The significance of all the relationships was not testable since many of the error terms were not normally distributed; however, the "R^2" values indicated that all of the relationships, except for the shortbill spearfish, account for a high percentage of the variance in the data. Hence, on the basis of fit and amount of variance accounted for, these relationships should be good predictors.

However, the usefulness of the relationships as predictors also varies according to the amount of

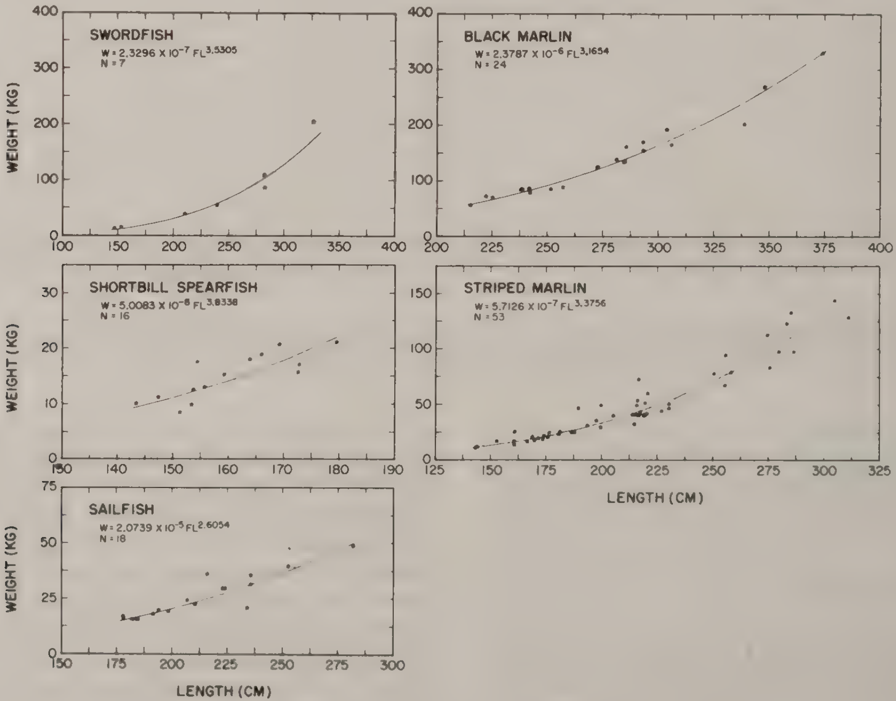

Figure 4.—Weight-length relationships using the log-linear model for swordfish, shortbill spearfish, sailfish, black marlin, and striped marlin.

Table 4.—Final weight-length relationships using the log-linear model, $W = bL^{a}\epsilon$, for the indicated data sets. H_N indicates the null hypothesis tested, and the accompanying alternate hypothesis was then H_A: $a \neq 3.0$. The data for the eastern tropical Pacific were obtained from Kume and Joseph (1969). Dashes indicate that the test could not validly be performed. Size ranges are in centimeters fork length.

Species	Data set	Sample size (N)	b	a	[1]t for H_N: $a = 3.0$	Size range	Eastern Tropical Pacific		
							b	a	Size range
Black marlin	Pooled	24	2.3787×10^{-6}	3.1654	1.447 NS	214.5-373.0	—	—	—
Blue marlin 50-135 cm FL	Longline	4	5.1827×10^{-1}	0.6678	−25.410**	50.0-135.0	—	—	—
Blue marlin ≥135 cm FL	Pooled	453	5.0048×10^{-6}	3.0214	—	135.0-456.9	—	—	—
	Longline	68	4.7226×10^{-6}	3.0442	0.595 NS	135.0-401.2	3.585×10^{5}	2.822	167.0-270.0
	Trolling	384	4.2968×10^{-6}	3.0470	—	156.0-389.2	—	—	—
	Trolling (male)	276	2.2929×10^{-5}	2.7405	—	176.5-311.0	—	—	—
	Trolling (female)	85	1.9445×10^{-6}	3.1871	1.986 NS	205.2-387.2	—	—	—
Sailfish	Pooled	18	2.0739×10^{-5}	2.6054	−1.429 NS	177.0-281.0	1.1596×10^{4}	2.461	134.0-205.0
Shortbill spearfish	Pooled	16	5.0083×10^{-8}	3.8338	1.115 NS	140.0-180.0	1.5320×10^{7}	3.724	128.0-156.0
Striped marlin	Pooled	53	5.7126×10^{-7}	3.3756	—	142.2-310.1	5.5564×10^{6}	3.089	108.0-211.0
Swordfish	Pooled	7	2.3296×10^{-7}	3.5305	3.135*	145.2-324.5	2.1115×10^{5}	2.961	131.0-229.0

[1] ** indicates significance at the 0.01 level, * indicates significance at the 0.05 level, and NS indicates not significant at the 0.05 level.

data used in the analysis, the range of the data, and whether sexes were analyzed separately. Considering the sample size (4) and the method of selecting the points of overlap, the relationship for small blue marlin (50-135 cm FL) was provisional. The relationship for shortbill spearfish was also provisional since there were 16 data points ranging from 140.0 to 180.0 cm FL. Although the sample sizes for black marlin, sailfish, and swordfish were small (24, 18, and 7, respectively), the ranges were wide, and the relationships should be taken as valid estimates. For striped marlin and for blue marlin, considering all data sets, there were enough data to obtain valid relationships. The importance of the results for the various blue marlin data sets will be discussed in connection with the coefficients of allometry.

Concrete interpretations of the coefficients of allometry are precluded by a statistical inability to test the significance of all the coefficients as well as to test between coefficients of different species or data sets. The coefficient for swordfish was the only one tested that was apparently greater than 3.0. For the other species tested, black marlin, blue marlin (longline data), female blue marlin (trolling data), sailfish, and shortbill spearfish, the hypothesis that the coefficient was equal to 3.0 could not be rejected. That is, the growth in weight to length was isometric for these species. Intuitively, we doubt these results for sailfish and shortbill spearfish and suspect that additional data would show the coefficient for sailfish to be less than isometry and for shortbill spearfish to be greater than isometry.

For blue marlin, the interpretation of the results was complicated by an inability to perform statistical tests of hypotheses. The coefficient of allometry for the small blue marlin indicated that the small fish maintain a very different weight to length growth relationship than do the larger, adult fish. Part of this difference may have been due to differential growth of the bill in the younger fish. It was apparent from Table 4 that there was not a real difference between longline- and troll-caught blue marlin; the coefficients of allometry as well as the intercept *"b"* were extremely similar. This does not necessarily imply that there are no seasonal differences in the weight-length relationship of blue marlin but does indicate that no such effect could be shown with 68 data points from longline catches made over all seasons. When the trolling data were divided according to sex, it was found that the coefficient for females did not differ significantly from isometry while that for males was probably less than isometry. The male and female curves (Fig. 5) could not be distinguished where the data overlapped. Hence, the increased weight to length growth shown by the females occurs primarily at lengths greater than those attained by males in this

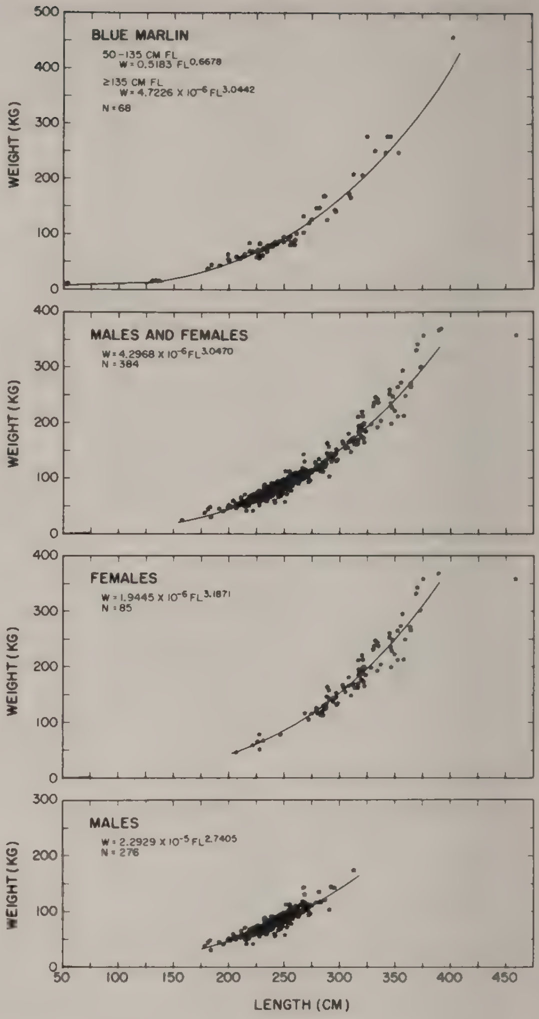

Figure 5.—Weight-length relationships using the log-linear model for blue marlin. The upper chart represents the relationships found for small and large fish using longline data. The remaining three charts represent relationships for sexes combined (including sex undetermined), females, and males using trolling data. The aberrant datum appearing in the sexes combined and female charts for the trolling data was not used in the calculation of the relationships.

data set. The sexual dimorphism in length that has been noted by many workers (e.g., Strasburg, 1970) apparently extends to the weight-length relationship also. That is, females not only grow to a greater length than males, but are proportionally heavier at the same length.

For striped marlin, analysis of the pooled data produced an estimate of the coefficient of allometry that appears to be greater than isometry. Inability to divide the data by sex was unfortunate since it is not known whether sexually dimorphic growth characteristics exist for the striped marlin. If such an effect does exist, it is believed to be less marked than in the blue marlin. Hence, the largeness of the striped marlin coefficient relative to that for the blue marlin, for both pooled and female data alone, probably was not due to sexual dimorphism.

There are only two papers in the literature giving weight-length relationships that may be compared to ours, since the data used by Royce (1957) were included in this analysis. De Sylva (1957) presented a length-weight plot for sailfish from the Atlantic Ocean, but a model was not fitted to the data. A fish approximately 250 cm FL would weigh 34 kg whereas our study predicts 37 kg. Kume and Joseph (1969) fitted the log-linear model to blue marlin, sailfish, shortbill spearfish, striped marlin, and swordfish data. The coefficients of allometry and the intercept points from their calculations are presented in Table 4 for direct comparison to those from this study. For all species, the coefficients of allometry for fish from the central Pacific were greater than those from the eastern tropical Pacific. If the coefficients were shown to be statistically different, there would be little point in comparing the intercept values since the relationships would already have been shown to be different. However, since the intercept value is related to the coefficient of condition, it should be noted that all of the intercept values for the central Pacific fish were smaller than those for the eastern tropical Pacific fish by a factor of 10. These differences may not be real because the samples for the central Pacific contained larger individuals than did the samples for the eastern tropical Pacific.

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Food and Feeding Habits of Swordfish, *Xiphias gladius* Linnaeus, in the Northwest Atlantic Ocean

W.B. SCOTT[1] and S.N. TIBBO[2]

ABSTRACT

Food and feeding habits of swordfish were studied by examining stomachs of 141 individuals captured from July to October 1971 between the Grand Bank and the southeast part of Georges Bank in the Northwest Atlantic Ocean. A wide variety of fish species made up about 80% of the diet; the remainder was squid. Species and size composition of food fishes depended on the feeding area. Large redfish *(Sebastes marinus)* were the most important food item in the Western Bank and Grand Bank areas, whereas silver hake *(Merluccius bilinearis)* made the greatest contribution in the Georges Bank area. Barracudinas, family Paralepididae, occurred most frequently and constituted about 20 percent of the fish diet for all areas. Sabertoothed fishes, family Evermannellidae, also occurred in samples from all areas.

The fact that swordfish are caught commercially on baited hooks gives special significance to knowledge of their food and feeding habits.

Scott and Tibbo (1968) reported on stomach contents of about 500 swordfish taken in the Northwest Atlantic Ocean and noted that fish and squid *(Illex illecebrosus)* constituted the principal food. Fish outnumbered squid about 3:1 volumetrically. The most important fish species were mackerel *(Scomber scombrus),* white barracudina *(Notolepis rissoi),* silver hake *(Merluccius bilinearis),* redfish *(Sebastes marinus),* and the herring *(Clupea harengus).* A total of 31 taxa (species and families) was represented.

In 1971, an additional 141 stomachs were analyzed and, although the results were more or less in basic agreement with the 1968 findings, sufficient deviation occurred to warrant additional comments. The 1971 study also included analysis of musculature of ingested species (fishes and squid) for mercury content, in an attempt to learn more about the source of mercury in swordfish flesh.

MATERIALS AND METHODS

Study material consisted of 141 swordfish stomachs collected during four cruises in the summer and autumn of 1971 (Figure 1). All fish were caught on longlines, using mackerel as bait. Stomach contents were preserved at sea, and identifications and volumetric analyses made later in the laboratory. Every effort was made to identify fishes to species. Amounts of fish and squid in stomachs were measured separately, and then summed to provide a figure of total volume of stomach contents for each swordfish.

After identification, samples of all ingested

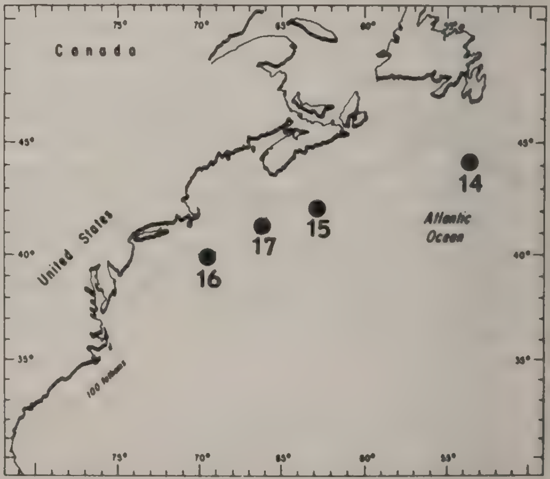

Figure 1.—Map showing locations of 1971 swordfish catches.

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species were retained for determination of mercury content.

RESULTS

Stomach analyses

Sixteen families of fishes and the short-finned squid *(I. illecebrosus)* were identified from 141 swordfish stomachs. One stomach contained the remains of two octopi.

Percentages by volume of fish (all species) versus squid in stomachs ranged from 78.7 to 94.0% (Table 1). These results are consistent with our earlier findings of 68.4 to 86.2% (Scott and Tibbo, 1968) and confirm the importance of fish in the diet of swordfish in the Northwest Atlantic. However, the species of fishes and the amount of squid in stomachs varied with feeding areas. In the Grand Bank and Banquereau regions, twice as much squid (121.5 cc average per stomach) occurred in stomachs as in samples from Emerald Bank (62.9 cc average per stomach) (Table 1). Also, in the Grand Bank region, the volume of redfish eaten was greater than for any other species, whereas the silver hake *(M. bilinearis)* was absent from the diet. The sample from Emerald Bank region, however, contained a greater volume of silver hake than any other fish except the bait, mackerel.

Total and average volumes of all food in swordfish stomachs for the different size groups are given in Table 2. The figures for average volume within each size group show that volumes increase with increase in size of swordfish, as might be expected. The average volume of food within each size group was similar for both the 1964-65 and 1971 samples.

In general swordfish feed on fewer fish species and on more squid in the Grand Bank and Banquereau regions than in those areas to the south and west. The number of fish species increases and the amount of squid in the stomachs decreases in regions to the south and west, particularly Browns and Georges banks and offshore canyons such as Lydonia, Hydrographer, and Washington.

Table 1.—Volumes (cc) of fish and squid in swordfish stomachs from 1971 samples.

No. of Stomachs Examined	Fish		Squid		Total Fish and Squid	Percent Fish
	Total	Average	Total	Average		
50	24,126	482.5	6,073	121.5	30,199	79.9
45	14,524	322.7	2.833	62.9	17,357	83.7
37	10,052	271.7	2,717	73.4	12,769	78.7
9	1,764	196.0	112	12.4	1,876	94.0

Table 2.—Average volumes of all food in swordfish stomachs arranged by length groups of swordfish for 1964-65 and 1971 samples.

Size Group (fork length)	1964-65		1971	
	Stomachs Examined	Average Volume	Stomachs Examined	Average Volume
(cm)	(number)	(cc)	(number)	(cc)
60- 79	1	20.0	3	68.3
80- 99	4	300.0	7	146.3
100-119	16	165.3	12	261.4
120-139	27	329.3	30	328.4
140-159	31	680.7	52	410.3
160-179	32	665.3	25	632.6
180-199	20	882.9	9	850.1
200-219	4	957.5	1	675.0
220-239	—	—	1	1,715.0
240-259	—	—	1	792.0

Fishes

The 16 families of fishes eaten are listed in Table 3. The first five food items are of primary importance and constitute 84.7% by volume of the total fish ingested. The remaining 11 families are of secondary importance (6.9%) and, indeed, some of these, such as the pearlsides *(Maurolicus muelleri)*, may be rare in the diet, since this is our first report of the species from a swordfish stomach. Unidentified fishes constituted 8.4% of the total.

Mackerel *(S. scombrus)* deserves special mention because it was used as bait. Also, there is evidence of "bait robbing"; that is, two or more mackerel, bearing evidence of hook marks, were found in a single stomach, suggesting that swordfish successfully remove bait from hooks. The usual condition was one mackerel, presumably bait, per stomach. Occasionally, the remains of two mackerel were present. On two occasions three occurred in a single stomach and on one occasion five mackerel were eaten by one swordfish. However, the state of digestion often obscures hook marks. Special marking of bait would be most helpful in determining the role of mackerel in the natural diet of swordfish. Undoubtedly, the large volume of mackerel in the diet, representing 36% of the total, is an unnatural condition.

Barracudinas, family Paralepididae, were the

Table 3.—List of fish species and families identified in swordfish stomachs, showing total volume (cc) of each for 1971 samples.

Fish	Total volume
Scombridae (Mackerels)	
Scomber scombrus (Atlantic mackerel)	18,110
Paralepididae (Barracudinas)	10,017
Scorpaenidae (Scorpionfishes)	
Sebastes marinus (Redfish)	7,355
Myctophidae (Lanternfishes)	3,802
Gadidae (Cods)	
Merluccius bilinearis (Silver hake)	3,485
Alepisauridae (Lancetfishes)	
Alepisaurus ferox (Longnose lancetfish)	1,365
Stromateidae (Butterfishes)	
Centrolophus niger (Black ruff)	1,005
Balistidae (Triggerfishes and Filefishes)	455
Evermannellidae (Saber-toothed fishes)	198
Malacosteidae (Loosejaws)	
Malacosteus niger (Loosejaw)	160
Carangidae (Jacks and Pompanos)	100
Nemichthyidae (Snipe eels)	
Nemichthys scolopaceous (Slender snipe eel)	97
Stomiatidae (Scaled dragonfishes)	
Stomias boa ferox (Boa dragonfish)	40
Gempylidae (Snake mackerels)	
Nealotus tripes	40
Scomberesocidae (Sauries)	
Scomberesox saurus (Atlantic saury)	16
Gonostomatidae (Anglemouths)	
Maurolicus muelleri (Müller's pearlsides)	2
Unidentified fishes	4,219
Total	50,466

most important single fish group recorded, except mackerel, and made up 20% of the fish diet. They occurred in samples from three stations, to as many as 78 individuals in a single stomach. More barracudinas (781) were eaten by swordfish of all sizes than any other fish species. Many were slashed. White barracudina *(Notolepis rissoi)* was the principal species involved but the short barracudina *(Paralepis atlantica)* was also identified. However, identification to species is exceedingly difficult with mutilated remains.

Redfish *(S. marinus)* was second in importance in terms of total volume eaten but was obviously of local or regional significance since it occurred only in Grand Bank and Western Bank samples. Also, redfish appear to be eaten mainly by larger (over 160 cm total length) swordfish.

Lanternfishes, family Myctophidae, were next in importance, occurring in three of four samples, and were represented by at least three species, *Myctophum punctatum, Notoscopelus kroyeri,* and *Benthosema glaciale.* A total of 441 individual myctophids was eaten by swordfish of all sizes and as many as 80 taken from a single stomach.

Silver hake *(M. bilinearis)* occurred in three of four samples and is considered to be the fifth of the five groups of primary importance. As noted previously, it did not appear in the Grand Bank sample but did occur in samples from the Scotian Banks, where silver hake is more common.

The remaining 11 families of fishes (Table 3) found occasionally in the stomachs are of unknown importance in the swordfish diet. One of these, the saber-toothed fishes, family Evermannellidae, is of interest because it occurred in all four samples, a total of 17 individuals, yet the family has not previously been reported from the area. The black ruff, *Centrolophus niger,* family Stromateidae, although reported from this region of the Northwest Atlantic (Templeman and Haedrich, 1966), has not previously been found in swordfish stomachs.

Squid

The short-finned squid *(I. illecebrosus),* like the barracudinas and myctophids, is eaten by swordfish of all sizes. As many as 27 pairs of squid beaks were found in single stomachs. On the average, more squid were found in stomachs of swordfish caught on Grand Bank and Banquereau than to the west and south.

SUMMARY

Species of primary importance in the swordfish diet were squid *(I. illecebrosus),* mackerel *(S. scombrus),* barracudinas (family Paralepididae), redfish *(S. marinus),* lanternfishes (family Myctophidae), and silver hake *(M. bilinearis).* Fishes contributed greater volume to the diet than squid, the percentage contribution ranging from 78.7% to 94.0%. The volume of squid in stomachs was higher in samples from the Grand Bank region than elsewhere. The total volume of food in stomachs increased with increase in size of swordfish.

The species of fishes eaten varied with the feeding area but the number of species increased southwestward. Barracudinas were the most important fish group, except mackerel, in all areas. The role of mackerel in the natural diet is obscure because it was used as bait.

Specimens of the saber-toothed fishes, family

Evermannellidae, were found in stomachs from all four areas.

ACKNOWLEDGMENTS

Many people were involved in the gathering of the data in the field and laboratory. We are pleased to acknowledge the help of the staff of the Biological Station, St. Andrews, New Brunswick, and of the Royal Ontario Museum, Toronto, Ontario.

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Maturation and Fecundity of Swordfish, *Xiphias gladius,* from Hawaiian Waters

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ABSTRACT

Sixteen swordfish, *Xiphias gladius,* ovaries ranging in weight from 39 to 20,000 g were examined. Fish size ranged from 47 to 246 kg. Based on the occurrence of ripe ovaries, spawning in Hawaiian waters was estimated to extend from April through July. The developmental stages of ova are described; the most advanced ova examined averaged 1.6 mm in diameter. The distribution of ova diameters within an ovary was found to be heterogeneous. Fecundity was estimated for eight swordfish. Some variability in fecundity was noted; a positive curvilinear relationship of increase in fecundity with increase in fish size was evident. Best estimates suggest that an 80 kg swordfish has 3.0 million ova (early ripe or ripe stages) and a 200 kg swordfish has 6.2 million ova.

The occurrence in Hawaiian waters of mature swordfish, *Xiphias gladius,* with ovaries in advanced stages of maturation has been observed in the past by longline fishermen and other members of the fishing industry. However, precise information of the spawning period and the fecundity of swordfish from the Hawaiian Islands area is lacking. Although swordfish are not taken in large numbers by the longline fishery (Fig. 1), the absence of studies on swordfish has been due principally to difficulty in obtaining adequate data. The large ovaries of swordfish along with ovaries of other billfishes and tunas are commercially valuable and considered as a food delicacy in Hawaii. Thus, in order to prevent damage to the gonads, the auction firms handling the sale of swordfish do not permit the fish to be cut open prior to sale. Since fish are often butchered outside of the auction area, we were unable to obtain the needed information on sex and maturity. Although very little data on swordfish were available during our six years of sampling (1961-66), we were able to collect 16 ovaries covering all seasons of the year. These samples and related data on swordfish were considered adequate to permit us to make a preliminary assessment of spawning and fecundity of swordfish; the results are presented in this paper.

OCCURRENCE OF SWORDFISH IN HAWAIIAN WATERS

Swordfish are taken exclusively with longline fishing gear in Hawaiian waters. The swordfish catch landed by the Hawaiian fishery is very small; the total annual catch did not exceed 120 fish during the six years of sampling (Fig. 1). Since fishing for

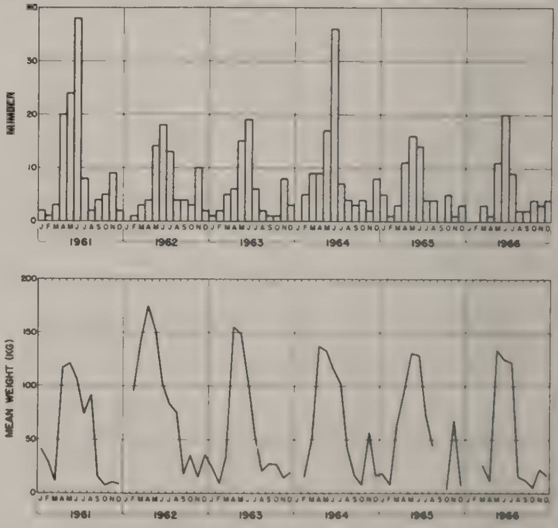

Figure 1.—Monthly landings of swordfish (upper panel) and average size of fish (lower panel) from 1961 to 1966.

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swordfish with longline gear is more successful during the night than day (Ueyanagi, 1974), the low catches may only be reflecting the fact that the Hawaiian fishery operates principally during daylight hours. Day fishing is carried out to maximize the catch of tunas and species of billfishes other than swordfish.

Figure 1 shows the monthly landings of swordfish for the period 1961-66. Although catches are small, there is a pronounced increase in landings during the summer months with the peak occurring in July. The increase is due to an increase in availability and not to an increase in fishing effort, since Yoshida (1974) showed that the catch rates (catch per trip) for blue marlin, *Makaira nigricans,* and striped marlin, *Tetrapterus audax,* in the Hawaiian longline fishery parallel the monthly landings, thus suggesting that the monthly catch data could be used as a general measure of availability.

The average size of swordfish also shows a peak during the summer period. As it will be discussed later, the increase in average size accompanied by the appearance of females in late stages of maturation may be related to a spawning migration.

MATERIALS AND METHODS

The 16 swordfish ovaries were collected at the Honolulu fish markets between June 1964 and May 1967 (Table 1). Since longline-caught fish are kept refrigerated with crushed ice, the ovaries were kept in an unfrozen condition until collected.

In the laboratory, excess connective tissue was removed from the external surfaces of the ovaries. The ovaries were weighed to the nearest gram and preserved in 10% Formalin. Detailed microscopic examination of the ovaries was undertaken only after the ovarian material had been thoroughly preserved, and shrinkage had stabilized. Generally, ova diameter measurements were taken after preservation had exceeded 6 mo.

For the maturation study, a small sample was extracted from the ovary with a cork borer and 100 randomly selected ova were measured to obtain mean diameter values for the most developed ova size group. Individual ova diameters obtained were not necessarily the maximum diameters. We followed the method developed by Yuen (1955) for measuring bigeye tuna ova and used by Otsu and

Table 1.—Summary of swordfish data used in maturation and fecundity study.

			Paired ovary weights			Most advanced mode			
Sample number	Date of landing	Fish size (kg)	Fresh (g)	Preserved in 10% Formalin (g)	Maturity[1]	Mean diameter (mm)	Number measured	Fecundity (millions of ova)	Gonad[2] index
BB-1	6/24/64	187.2	11,566	10,033	ER, RS	1.019	153	2.24	6.18
BB-2	6/25/64	121.5	10,205	6,805	RP	1.205	257	3.84	8.40
BB-3	6/25/64	204.1	19,958	19,609	RP, RS	1.364	172	6.18	9.78
BB-4	7/ 3/64	156.5	9,389	(8,267)[3]	ER	0.986	228	4.80	6.00
BB-5	7/ 3/64	142.4	8,373	(7,332)[3]	ER	0.923	403	9.38	5.88
BB-6	7/ 6/64	246.3	1,542	1,430	ED, RS	0.101	100	—	0.63
BB-7	7/17/64	86.6	184	169	IM	0.060	100	—	0.22
BB-8	11/26/65	17.7	39	39	IM	0.057	100	—	0.22
BB-9	1/ 2/66	68.0	508	490	ED	0.141	100	—	0.75
BB-10	1/25/67	90.3	390	415	ED	0.154	100	—	0.43
BB-11	2/24/67	46.7	(Damaged)						
BB-12	4/ 5/67	54.4	172	174	ED	0.107	100	—	0.32
BB-13	4/13/67	76.6	163	176	IM	(poorly preserved)			0.21
BB-14	4/27/67	121.5	8,164	(7,187)[3]	RP	1.438[4]	113	3.73	6.72
BB-15	5/22/67	83.0	4,327	4,200	ER	0.990	306	3.21	5.21
BB-16	5/28/67	202.7	8,255	8.197	ER, RS	1.033	296	6.54	4.07

[1] Key: IM - Immature
ED - Early developing
ER - Early ripe
RP - Ripe
RS - Residual eggs present

[2] Gonad index is percentage of fresh ovary weight to fish size.

[3] Weight estimated from fresh-preserved conversion given in Figure 2.

[4] Ova diameters of fresh (non-preserved) samples placed in sea water averaged 1.571 mm.

Uchida (1959) for albacore. The measurement was the random diameter located parallel to the ruled lines marked on the measuring dish.

For ovaries in the early ripe or ripe stages, ova diameters were taken to obtain the mean diameter of the most advanced mode. A small sample of the ovarian tissue was extracted with a cork borer from the area near the lumen of the posterior region of the right ovary. Excess liquid was first blotted out and the sample weighed on an analytical balance. All ova in the most advanced stage were measured and counted, the latter to obtain fecundity estimates.

Weights of preserved ovaries from four fish were not recorded (Table 1). Since three of these samples were in the early ripe or ripe stages of maturity and could be used for fecundity estimates, we computed a conversion factor to correct for shrinkage due to preservation. Figure 2 shows the regression of fresh whole ovary weight on preserved (10% Formalin) ovary weight. The regression computed on the transformed data (log $_e$) shows a very good fit for the 12 sets of data. The equation was used to estimate the preserved weights of the three samples (Table 1).

Sample BB-3 (Table 1) was used to test for homogeneity of ova diameters within a pair of ovaries. A cork borer (14.29 mm diameter) was used to obtain a core sample which extended from the outer surface of the ovary to the centrally-located lumen. The core was divided into an outer layer, a central layer located next to the lumen, and a middle layer. Separate cores were taken from the anterior, middle, and posterior region of both ovaries, thus providing a total of 18 subsamples. Ripe ova were teased from each sample and 200 randomly-selected ova were measured

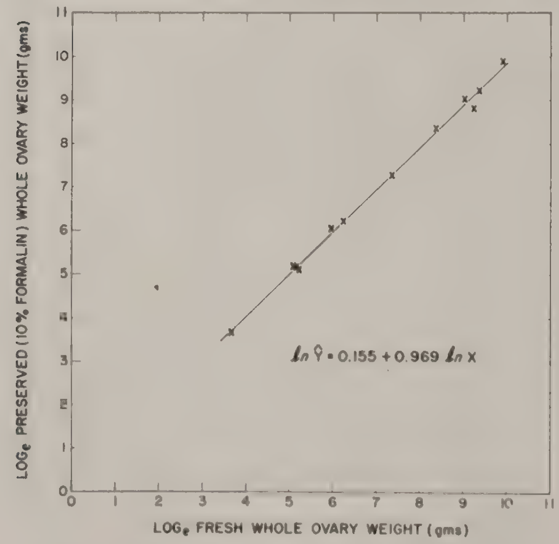

Figure 2.—Relationship of fresh ovary weight to preserved (10% Formalin) ovary weight for swordfish.

DEVELOPMENTAL STAGES OF OVA

An examination of the physical appearance of ova from swordfish showed that the ova could be classified easily into several developmental stages which were not dependent on ova diameters. The stages are described as follows:

1. Primordial Ova
   Ova are transparent, ovoid in shape, and diameters range from 0.01 to 0.05 mm. Primordial ova are present in all ovaries.
2. Early Developing Ova
   Ova are still transparent and ovoid in shape; diameters range from approximately 0.06 to 0.24 mm. A chorion membrane has developed around the ovum and an opaque yolk-like material has begun to be deposited within the ovum.
3. Developing Ova (Figure 3A)
   Ova are completely opaque, more wedge-shaped than ovoid, and diameters range between 0.16 to 0.96 mm. The chorion is stretched and not visible in this stage.
4. Advanced Developing Ova (Figure 3B)
   Ova are ovoid and diameters range from 0.47 to 1.20 mm. Ova have a translucent margin, a fertilization membrane, and a round yolk.
5. Early Ripe Ova (Figure 3C)
   Ova diameters range from 0.60 to 1.20 mm. The yolk material is translucent and oil globules have begun to form.
6. Ripe Ova (Figure 3D)
   Ova are transparent and with oil globules. Diameters range from 0.80 to 1.66 mm.
7. Residual Ova
   Ova in this stage show signs of degeneration. Ova are thin-walled and translucent and have shrunken and measure approximately 0.80 mm in diameter.

HETEROGENEITY OF OVA DIAMETERS

The distribution of ova diameters in sample BB-3 was examined critically to test for heterogeneity. A chi-square test of the normality of the size frequency distribution of ova diameters for the 18 samples (Appendix Table 1) showed significant differences fo

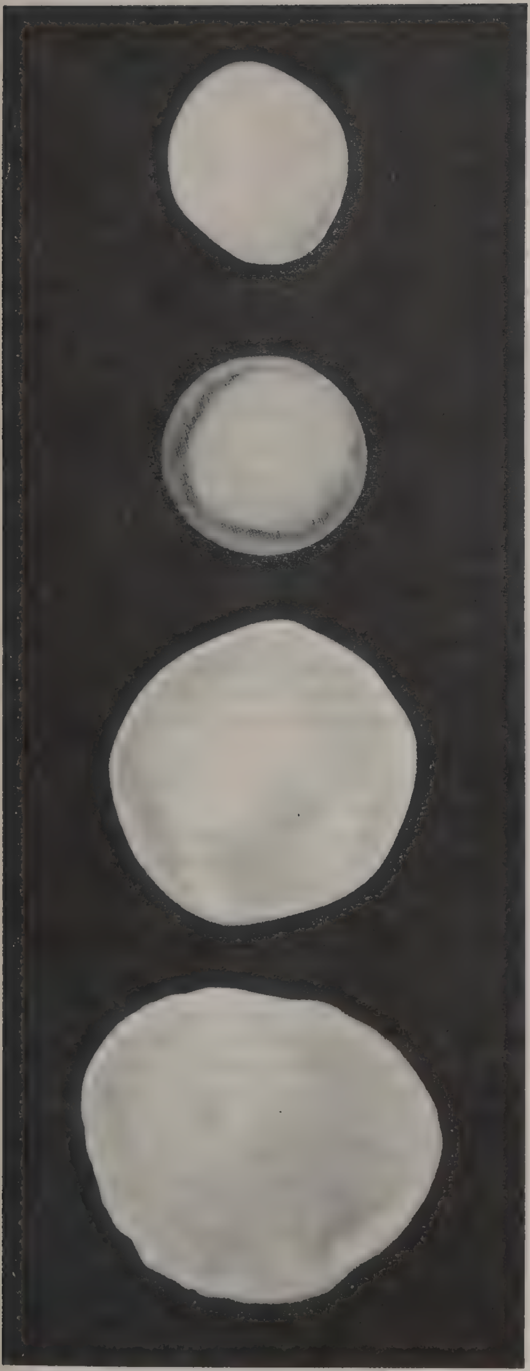

Figure 3.—Developmental stages of swordfish ova. **A.** Developing. **B.** Advanced developing. **C.** Early ripe. **D.** Ripe.

sample RMO ($P = 0.01$) and samples RMC and RPO ($P = 0.05$). An analysis of variance for one-way design was used to test for homogeneity (Table 2). The null hypothesis that the distribution of ripe ova was homogeneous throughout the ovaries was rejected ($P<0.05$; F ratio of 5.2821; *d.f.* 17 and 3,582). An examination of the means showed no general trends with the different sections of each ovary and locations within each section. The lack of homogeneity in ova has also been demonstrated for bigeye tuna (Yuen, 1955) and albacore (Otsu and Uchida, 1959).

A further evidence of heterogeneity was indicated in a comparison of ripe and early ripe ova. Table 3 shows the number of ripe and early ripe ova from the nine locations sampled from the right ovary. The ratio of ripe to early ripe ova ranged from 0.5576 to 2.6792. Three samples, RPC, RPM, and RMC, had almost identical ratios; but no consistent pattern was evident.

SPAWNING

Swordfish with ovaries in a ripe condition have been reported in the Mediterranean Sea off Sicily (Sella, 1911), in the Gulf Stream off Cuba (LaMonte, 1944) and in the western Pacific Ocean in the seas adjacent to Minami Tori Shima located at long. 156°E, lat. 25°17′N (Nakamura et al., 1951). Yabe et al. (1959) reported the occurrence of swordfish with ripe ovaries in the North Pacific Ocean in waters extending from the Subtropical Convergence to the equator and in the South Pacific in the Coral Sea and near the Fiji Islands. Yabe et al. (1959) also reported on the occurrence of seven ripe ovaries taken from swordfish caught in the Indian Ocean.

The appearance in April through July (Table 1) of large swordfish in the late stages of maturity suggests that the movement into coastal waters of the Hawaiian archipelago may be part of a spawning migration. Matsumoto and Kazama (1974) identified swordfish larvae from plankton hauls taken in Hawaiian waters, thus confirming the indirect evidence based on our ovary maturation study. Cavaliere (1962) reported that embryos start to form in eggs with diameters between 1.60 and 1.80 mm. In our samples the mean ova diameters of the most advanced modes of the preserved material were 1.20 mm for sample BB-2, 1.36 mm for BB-3, and 1.44 mm for BB-14. Ova from sample BB-14, which had been immersed in seawater prior to preservation, had a mean diameter of 1.57 mm. Since the gonad

Table 2.—Test of ova diameters from selected locations from right and left ovary of sample BB-3; analysis of variance for one-way design.

Treatment[1]	Sample size	Mean micrometer units	Standard deviation	Mean (mm)
RAC	200	69.38500	6.133913	1.4223
RAM	200	69.93500	6.480799	1.4336
RAO	200	68.41500	7.441750	1.4025
RMC	200	67.51500	7.646705	1.3840
RMM	200	67.51000	7.418561	1.3839
RMO	200	67.93500	8.098684	1.3926
RPC	200	69.44500	7.664900	1.4236
RPM	200	69.94000	7.077913	1.4337
RPO	200	72.00000	6.587639	1.4760
LAC	200	68.96500	6.347853	1.4137
LAM	200	69.97000	6.592144	1.4343
LAO	200	70.19000	6.296197	1.4388
LMC	200	69.86000	5.928416	1.4229
LMM	200	68.19500	6.523783	1.3979
LMO	200	69.48500	6.331683	1.4244
LPC	200	69.41000	5.725012	1.4229
LPM	200	69.40500	6.811972	1.4336
LPO	200	69.80000	5.445941	1.4309

Analysis of Variance

	Sum of squares	*d.f.*	Mean square	*F* ratio
Between groups	4072.5925	17	239.5643	5.2821
Within groups	162458.1074	3582	45.3540	
Total	166530.6992	3599		

[1] RAC - Right anterior center
RAM - Right anterior mid-layer
RAO - Right anterior outer layer
RMC - Right middle region center
RMM - Right middle region mid-layer
RMO - Right middle region outer layer
RPC - Right posterior region center
RPM - Right posterior region mid-layer
RPO - Right posterior region outer layer
LAC - Left anterior center
LAM - Left anterior mid-layer
LAO - Left anterior outer layer
LMC - Left middle region center
LMM - Left middle region mid-layer
LMO - Left middle region outer layer
LPC - Left posterior region center
LPM - Left posterior region mid-layer
LPO - Left posterior region outer layer

index measures gonad size relative to fish size, it is not surprising to find that the highest gonad indices occurred during the apparent spawning period April to July (Table 1).

Since residual ova are remains from previous spawning (Yuen and June, 1957), all ovaries from our collection were examined for these ova. Residual ova were only evident in some of the samples collected in May, June, and July (Table 1). Although Yabe, et al. (1959), assumed that the ripe ova (modal diameter 1.2 mm to 1.6 mm) were spawned at one time, partial spawning of swordfish cannot be discounted as sample BB-3, which was judged ripe, also had residual ova.

Table 3.—Ratio of numbers of ripe to early ripe ova.

Sample[1]	Number of early ripe ova	Number of ripe ova	Ratio index
RAC	170	212	1.2470
RAM	195	291	1.4923
RAO	220	256	1.1636
RMC	303	269	.8877
RMM	319	212	.6645
RMO	477	266	.5576
RPC	194	172	.8865
RPM	280	248	.8857
RPO	106	284	2.6792

[1] RAC - Right anterior center
RAM - Right anterior mid-layer
RAO - Right anterior outer layer
RMC - Right middle region center
RMM - Right middle region mid-layer
RMO - Right middle region outer layer
RPC - Right posterior region center
RPM - Right posterior region mid-layer
RPO - Right posterior region outer layer

It is interesting to note that Sella (1911) reported that the swordfish ovary contracts after spawning and remains compact and firm. This differs from tunas, which tend to be noticeably flaccid (Yuen, 1955). Sample BB-6, which was collected in July, appeared to confirm the general condition described for swordfish. Although this ovary was in an early stage of maturity and was firm and compact, it also contained residual ova, suggesting recent spawning.

No early ripe or ripe ovaries were collected from August to April. To some extent this feature may only reflect absence of mature fish, since nearly all of the swordfish taken during this period were small in size (Table 1) and indicative of immature fish.

FECUNDITY

Fecundity estimates are presented in Table 1 and shown in Figure 4. Since homogeneity tests showed significant differences in the distribution of ova diameters within a single pair of ovaries, the estimates should be considered only as rough approximations of the true fecundity of the swordfish. It

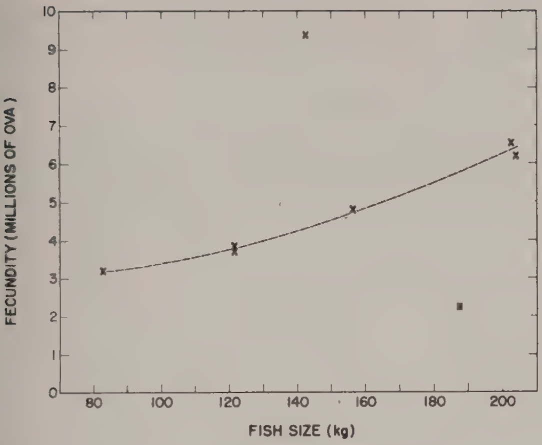

Figure 4.—Fecundity estimates for swordfish from Hawaiian waters.

should be pointed out, however, that while nonrandom distribution of ova diameters within an ovary may contribute to errors in fecundity estimates, other factors are equally important in making the current methods of measuring fecundity difficult. Other factors include inaccurate estimates of the true ovary weight due to varying amounts of connective tissue left on the ovary surface, and more important, the varying amount of excess fluids (primarily the preservative) removed from the ovary during the "draining" period. Possibly the most important error factor may be related to the point in maturation when the fecundity estimates are made. In species with multimodal frequency distributions of ova diameters (Yuen, 1955; Otsu and Uchida, 1959), the most advanced modal size group has fewer ova than the modal groups to the left (smaller ova). This suggests that resorption of some ova is taking place. Thus, the final number of ova extruded during spawning is less than the number with which the modal group started when the mode first differentiated from the primordial ova stock.

Fecundity estimates of the eight swordfish with early ripe or ripe ova are shown in Figure 4. As indicated in an earlier section, fecundity estimates from three of the fish were based on preserved ovary weights which were estimated from fresh-preserved ovary weight relationship. In Figure 4 two of the eight points appear to be displaced a considerable distance from the general curvilinear relationship of increasing fecundity with increasing fish size. Sample BB-5 with an estimated 914 million ova is considerably higher than the general trend, while sample BB-1 with 2.2 million ova is on the lower side.

From our limited fecundity data, and considering the error factors described above, we estimate the fecundity of swordfish to range from 3.0 million ova for a fish weighing 80 kg to 6.2 million ova for a fish weighing 200 kg. Yabe et al. (1959) estimated the fecundity of a 186 cm (orbit to fork) swordfish to be between 3 and 4 million ripe ova.

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APPENDIX: Table 1.—Frequency distribution of ripe ova diameters from selected parts of a swordfish ovary (sample BB-3).

Ocular micrometer units	Millimeters	Subsamples[1] RAC	RAM	RAO	RMC	RMM	RMO	RPC	RPM	RPO	LAC	LAM	LAO	LMC	LMM	LMO	LPC	LPM	LPO
87	1.7835	1	—	1	2	—	—	2	—	1	—	—	—	—	—	—	—	—	—
86	1.7630	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
85	1.7425	—	2	—	—	—	—	1	—	—	—	—	1	—	—	—	1	—	—
84	1.7220	1	—	—	—	—	2	1	1	2	—	1	—	—	—	1	—	2	—
83	1.7015	—	—	1	1	—	2	3	2	5	1	1	1	—	1	—	—	1	1
82	1.6810	—	3	1	—	2	4	3	2	4	1	1	4	1	—	2	—	1	1
81	1.6605	2	2	1	3	2	3	2	4	2	3	3	2	3	2	1	1	1	2
80	1.6400	5	2	4	4	4	4	3	7	10	4	3	6	5	2	2	4	1	1
79	1.6195	4	4	6	3	4	3	2	2	7	—	5	2	2	4	4	3	8	3
78	1.5990	4	6	6	6	3	7	10	11	9	7	5	8	5	2	3	5	5	3
77	1.5785	4	6	9	1	8	2	13	14	12	5	8	8	10	4	8	11	9	11
76	1.5580	10	14	8	8	5	12	9	3	14	7	9	10	7	10	11	3	5	10
75	1.5375	4	11	8	12	8	10	5	13	7	11	6	3	10	5	12	9	13	12
74	1.5170	7	11	11	7	5	4	7	11	8	7	17	12	17	10	12	7	9	8
73	1.4965	11	13	7	10	12	7	10	13	20	16	20	15	13	11	13	14	14	11
72	1.4760	21	13	11	11	13	10	10	10	15	11	14	17	10	18	19	13	14	11
71	1.4555	18	16	6	4	7	8	9	6	7	16	16	18	11	9	11	14	18	16
70	1.4350	14	15	10	8	15	10	7	11	12	12	15	16	16	13	13	21	11	18
69	1.4145	10	5	11	6	7	7	8	8	10	7	11	4	9	14	8	13	6	12
68	1.3940	20	11	9	15	16	7	12	11	12	17	8	10	20	12	10	16	12	10
67	1.3735	14	11	19	11	8	13	11	8	14	12	5	12	12	10	16	10	11	21
66	1.3530	6	9	10	13	11	9	17	8	3	10	8	4	8	9	5	10	8	13
65	1.3325	7	6	12	11	10	16	6	7	3	5	7	12	9	8	6	5	5	6
64	1.3120	4	8	5	7	2	5	7	9	4	8	2	6	3	12	11	9	9	6
63	1.2915	10	4	8	13	6	9	4	9	4	6	7	6	4	9	5	7	5	6
62	1.2710	3	9	5	4	6	5	6	7	1	12	8	5	4	10	4	8	7	4
61	1.2505	3	3	3	3	6	8	9	2	2	4	5	4	4	3	2	4	9	2
60	1.2300	5	4	1	5	7	4	6	4	3	5	4	2	9	6	6	1	1	5
59	1.2095	2	3	2	4	5	3	2	5	2	1	—	1	1	1	3	2	1	1
58	1.1890	2	—	4	5	6	3	3	4	—	3	—	6	3	1	3	4	6	4
57	1.1685	1	2	6	6	5	9	2	2	1	2	2	—	—	4	2	1	1	1
56	1.1480	1	1	2	2	3	—	—	2	1	1	2	—	—	1	—	1	1	—
55	1.1275	2	1	1	2	6	4	1	1	1	1	—	1	2	2	2	—	1	—
54	1.1070	—	1	4	5	3	—	1	—	1	1	1	3	1	1	2	1	—	—
53	1.0865	2	—	2	2	1	1	1	1	—	1	1	—	—	1	1	1	1	—
52	1.0660	1	1	3	3	1	3	3	—	1	—	—	—	—	1	—	1	1	—
51	1.0455	—	1	—	1	—	2	1	—	2	2	2	1	—	1	1	—	—	—
50	1.0250	—	—	2	—	—	—	1	—	—	1	2	—	—	1	1	—	—	—
49	1.0045	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	
48	.9840	1	—	—	1	1	—	—	1	—	—	—	—	1	2	—	—	—	—
47	.9635	—	—	—	—	1	1	—	1	—	—	—	—	—	—	—	—	1	—
46	.9430	—	—	1	1	1	2	—	—	—	—	—	—	—	—	—	—	2	—
45	.9225	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—
44	.9020	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

[1] RAC - Right anterior center
RAM - Right anterior mid-layer
RAO - Right anterior outer layer
RMC - Right middle region center
RMM - Right middle region mid-layer
RMO - Right middle region outer layer
RPC - Right posterior region center
RPM - Right posterior region mid-layer
RPO - Right posterior region outer layer

LAC - Left anterior center
LAM - Left anterior mid-layer
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LMC - Left middle region center
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LPM - Left posterior region mid-layer
LPO - Left posterior region outer layer

Occurrence, Morphology, and Parasitism of Gastric Ulcers in Blue Marlin, *Makaira nigricans,* and Black Marlin, *Makaira indica,* from Hawaii

ROBERT T. B. IVERSEN[1] and RICHARD R. KELLEY[2]

ABSTRACT

Gastric ulcers were found in 10 of 114 blue marlin, *Makaira nigricans*, and 2 of 3 black marlin, *M. indica*, examined from 1967 to 1969 at the Hawaiian International Billfish Tournament. Parasitic nematodes were found imbedded in the base of ulcers in one blue marlin and two black marlin. The gross and microscopic morphology of the ulcers is given and possible causes are discussed. The most likely cause is either mechanical injury or parasites, or the effect of both in the same stomach.

The existence of gastric ulcers in man and other mammals, including marine mammals (Geraci and Gerstmann, 1966) is well known. The existence of gastric ulcers in fish was first noted by Aliverdiev and Radzhabov (1968), Evans and Wares (1972), and Iversen and Kelley (in press). We here report additional details on the occurrence, morphology, parasitism, and possible causes of gastric ulcers in blue marlin, *Makaira nigricans,* and black marlin, *M. indica,* landed from 1967 to 1969 during the annual Hawaiian International Billfish Tournament.

METHODS

One hundred seventeen marlin were captured during daytime trolling in surface or near surface waters just off the west coast of the Island of Hawaii. Each billfish tournament included 5 fishing days during either July or August. Fishing commenced each day at 0800, but the catch was usually not brought to the weighing station until after 1700 when fishing ended, so there often was a lengthy interval between capture and examination of the stomach. After being weighed by tournament officials, each fish was measured, sexed, and examined for stomach contents. Specimens were not refrigerated prior to examination. The estimated maximum interval between capture and examination of marlin containing ulcers was 7.5 h. Histological preparations were by standard paraffin imbedding with hematoxylin and eosin stain.

RESULTS

Ten of 114 blue marlin and 2 of 3 black marlin contained ulcers, for a combined occurrence of 10.3%. Sex, weight, and length for each marlin with ulcers are given in Table 1. Two black marlin and seven blue marlin stomachs with ulcers were preserved in 10% Formalin[3] for laboratory examination. Two of the black marlin and one of the blue marlin stomachs examined in the laboratory contained ulcers invaded by small parasitic nematodes, *Contracaecum* sp.?, a roundworm which has been reported in billfish stomachs from widely separated localities (Wallace and Wallace, 1942; Morrow, 1952).

The following brief comments on gross and microscopic morphology are based upon examination of one of the black marlin stomachs which contained numerous ulcers, both with and without nematodes. The comments are also descriptive of ulcers in blue marlin.

Gross Findings

The ulcers were either separate or in clusters

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[3] Reference to commercial products does not imply endorsement by the National Marine Fisheries Service.

Table 1.—Record of marlins with gastric ulcers captured at the Hawaiian International Billfish Tournament, 1967-69.

Date captured	Species	Sex	Wt.	Fork length[1]	Estimated elapsed time, capture to examination
			kg	*cm*	*h*
4 July, 1967	*Makaira nigricans*	F	151.5	303.4	5.5
6 July, 1967		M	141.0	290.0	3.5
29 July, 1968		M	67.6	224.9	6.5
29 July, 1968	*Makaira indica*	F	83.9	240.9	7.5
31 July, 1968		F	86.2	256.1	1.5
1 Aug., 1968	*Makaira nigricans*	M	92.5	256.8	5.0
2 Aug., 1968		M	67.6	230.3	3.0
2 Aug., 1968		F	189.1	315.7	6.5
2 Aug., 1968		F	102.0	270.3	7.5
21 Aug., 1969		M	102.0	268.2	6.5
21 Aug., 1969		M	66.7	236.4	6.5
22 Aug., 1969		M	68.5	235.3	7.0

[1] Tip of snout to center of distal edge of caudal fin.

throughout the stomach (Fig. 1). They were noncancerous. Edges were indurated and raised slightly from the surrounding surface. Ulcer margins were rather sharply demarcated. The bases were covered with a dark brown shaggy material and had an indurated feel. Light gray nematodes 5-7 mm in length and less than 0.5 mm in diameter were imbedded in the bases of four ulcers in this stomach (Fig. 2). The bases of the ulcers were very indurated and the induration extended through the wall of the specimen.

Microscopic Findings

The base of this ulcer was covered by granulation tissue with a dense proliferation of fibroblasts and an infiltration of acute and chronic inflammatory cells (Fig. 3). The fibrous proliferation extended through the entire wall and obliterated the usual muscular layers. Remnants of the nematodes were identified throughout the ulcer base. Generally, there was an intense granulomatosis inflammatory reaction surrounding the parasite. This consisted of inflammatory cells and histiocytes. In some instances the inflammatory reaction had subsided and only laminar layers of fibrous tissue remained (Fig. 4).

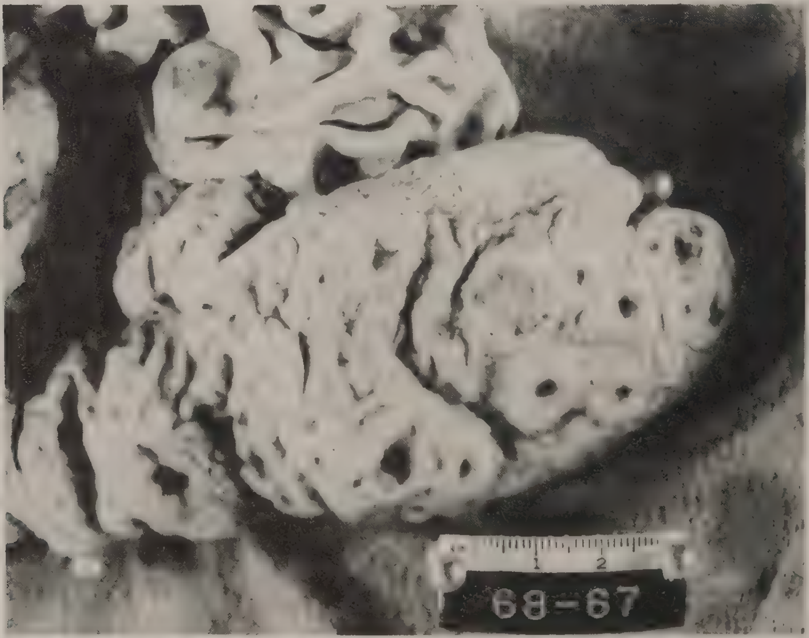

Figure 1.—Multiple ulcerations varying from 3 to 13 mm scattered over the mucosal surface of a stomach from a female black marlin. Weight of marlin 86.2 kg; fork length 256.1 cm.

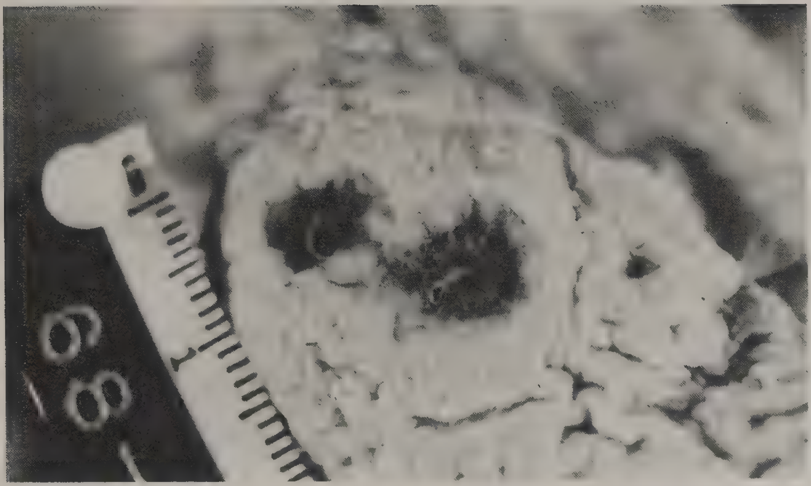

Figure 2.—Closeup view of same black marlin stomach showing nematodes burrowing in base of ulcer.

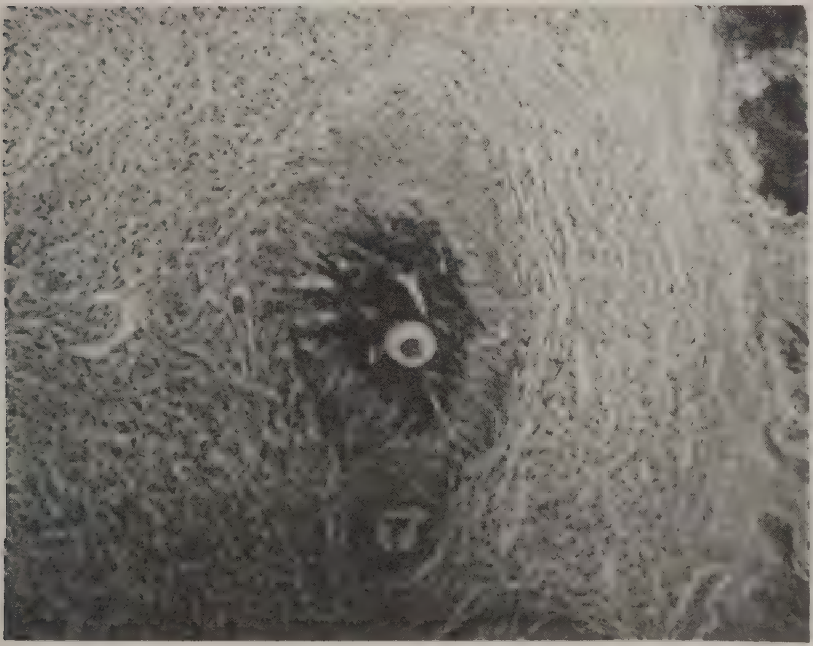

Figure 3.—Microscopic section of base of ulcer from same black marlin showing extensive fibrosis and subacute inflammatory response surrounding portions of nematode sectioned in two areas (H & E stain, 25×).

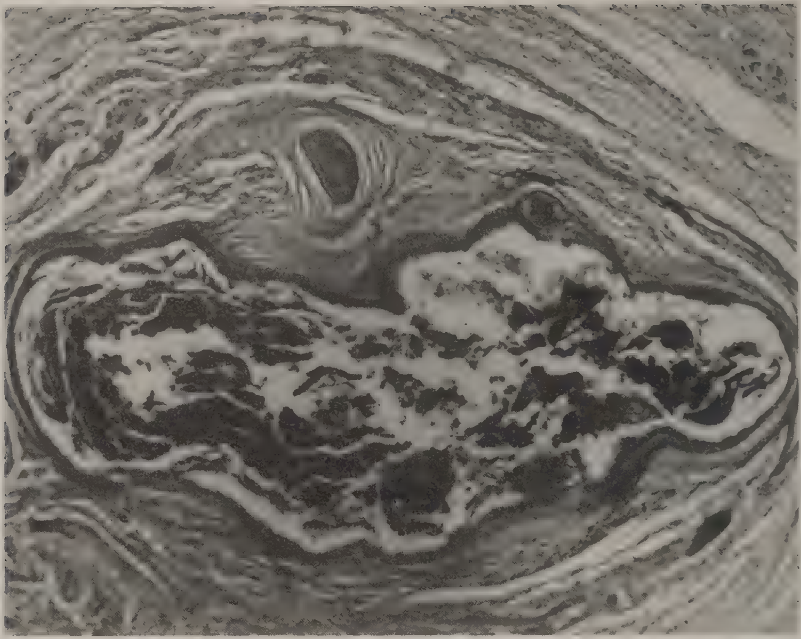

Figure 4.—Microscopic section of base of ulcer from same black marlin showing extensive fibrosis laminated around old nematodal debris (H & E stain, 25×).

DISCUSSION

Several possible causes of the ulcers may be considered. They are (1) mechanical injury to the stomach lining from sharply pointed food items, (2) parasites, (3) digestive processes due to gastric secretions between the time of death and time of examination, and (4) excess gastric secretions.

The most likely cause is either mechanical injury or parasites, or the effect of both in the same stomach. Blue and black marlins feed heavily on fish, many having sharply pointed projections. Examples are the dorsal spines of skipjack tuna, *Katsuwonus pelamis,* and yellowfin tuna, *Thunnus albacares*. Both of these tunas are commonly eaten by marlins. We have recovered a sliver of bonelike material from beneath the epithelium of the stomach of a marlin captured during a billfish tournament. Other examples are the spiny puffers, Diodontidae, which sometimes occur in marlin stomachs. Spiny puffer remains were found in one of the stomachs containing an ulcer, and it is possible that multiple punctures of the stomach lining could occur after engulfment of such food. Multiple punctures could also be caused by engulfment of prey items with sharp spines during successive feedings. This could explain instances of multiple ulcers in some of the marlin stomachs. Fo example, the black marlin stomach shown in Figur 1 had six ulcers wider than 10 mm and over 50 smal ler ulcers less than 10 mm wide.

Evans and Wares (1972) reported finding gastri ulcers in 14% of 563 striped marlin, *Tetrapturu audax,* and 22% of 151 sailfish, *Istiophoru platypterus,* examined in Mexican and souther California waters in 1968. They did not, however cite the presence of nematodes, either in stomach with or without ulcers. They also suggest spines o prey species may have caused the ulcers.

In those ulcers containing nematodes, it is uncer tain if the ulcers were caused by the nematodes, or i the nematodes took advantage of the ulcer and bur rowed inward. Other workers have found a hig percentage occurrence of nematodes in marli stomachs without citing the presence of ulcers. Wal lace and Wallace (1942) found *Contracaecum incur vum* in 60 of 86 stomachs of white marlin, *T. albidus* captured off Ocean City, Maryland. Morrow (1952 reported finding *C. incurvum* in each of 5 stomachs of striped marlin, *M. mitsukurii* (= T *audax*), from New Zealand. If this nematod causes ulcers, its association with ulcers should b common, which is not the case, according to pub lished reports. This implies mechanical injury is the most likely cause, with the ulcers being further aggravated in those stomachs containing parasitic nematodes.

Digestive action by gastric secretions after death is another possibility, but it seems highly unlikely the large size of some ulcers could develop even during the lengthy interval between capture and preservation of the stomach. For example, the 83.9 kg black marlin captured in 1968 had one ulcer that was 40 mm long, 27 mm wide, and 10 mm deep (measurements after preservation in Formalin). In addition, 30 nematodes and necrotic tissue were present in the pit of this ulcer.

High concentrations of free circulating histamine might possibly cause ulcers by increasing gastric acid secretions. It is known that histamine has an ulcerogenic effect on warm-blooded animals (Hay et al., 1942). Geraci and Gerstmann (1966) have suggested that histamine from a diet of inadequately preserved fish caused gastric ulcers in a captive bottle-nosed dolphin, *Tursiops truncatus*. Fresh fish contain negligible amounts of histamine, but under conditions of inadequate preservation, decarboxylation results in the formation of histamine from histidine (Geraci and Gerstmann, 1966). Since marlin feed on fresh fish, it seems unlikely much of the prey's histidine may find its way into the marlin's blood stream as histamine. Further, the effect of histamine on gastric secretions in teleosts is unknown. In the spiny dogfish shark, *Squalus acanthias*, perfusion of isolated gastric mucosa with histamine resulted in an increased secretion of acid 1 to 1.5 times the amount secreted by isolated dogfish gastric mucosa not perfused with histamine, but high concentrations of histamine were required (Hogben, 1967).

Increased gastric secretion from behaviorally induced stress conceivably might have an ulcerogenic effect on marlin. The average sex ratio of blue marlin landed during Hawaiian International Billfish Tournaments from 1962 to 1972 has been 3.3 males:1 female, while blue marlin caught by commercial fishing in subsurface waters in Hawaii have an almost 1:1 sex ratio (Strasburg, 1970). It has been suggested the unequal sex ratio of blue marlin caught during the tournaments may indicate a spawning aggregation. Such an aggregation conceivably might be stress-inducing but this is highly speculative and probably unrelated to ulcer occurrence. Adequate data on the sex ratio of black marlin are not available.

ACKNOWLEDGMENTS

We gratefully acknowledge the cooperation of anglers and officials of the annual Hawaiian International Billfish Tournament in making these specimens available for examination.

We thank Ross F. Nigrelli, Donald W. Strasburg, and Heeny S. H. Yuen for reading the manuscript and for offering advice.

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Mercury in Swordfish and Other Pelagic Species from the Western Atlantic Ocean

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ABSTRACT

Total mercury determinations have been carried out on at least one tissue from each of 210 swordfish, 40 specimens of 15 other pelagic species, and 235 individuals of 12 species taken from swordfish stomachs. Total mercury levels of swordfish white muscle tissue ranged from 0.05 to 4.90 parts per million (ppm) (mean 1.15 ppm) total mercury. Mercury levels were broadly related to fish size with the larger fish having higher levels but the relationship varied with time and area of capture. Males tended to have higher levels than females. The mercury levels of different tissues (red muscle, liver, kidney, heart, brain, gill, vertebral disc, and stomach) are given. The differences in the levels in certain tissues from fish taken in different areas suggest greater physiological activity of mercury in fish from the southern area. The significance of mercury in swordfish prey species is discussed.

As a result of the sudden awareness of the presence of mercury in swordfish *(Xiphias gladius)* and the almost immediate cessation of the fishery in early 1971, there were very few specimens with good biological and capture data available for analysis. In order to investigate heavy metal contamination in fishes, the Fisheries Research Board of Canada conducted a series of longlining cruises (Table 1) in the area extending from the southern Caribbean to the Grand Banks. The results of the first five cruises from 1 August 1971 to March 1972 are presented here.

METHODS

Regular swordfish longlines were used, the general gear configuration being Mustad 3½/0 hooks[3] on 3-fathom gangings, attached to the mainline at 20-fathom intervals. The mainline was held near the surface by buoys, on 5-fathom lines, attached to it every 100 fathoms. The gear was set in the evening and hauled back after dawn. Mackerel *(Scomber scombrus)* and occasional herring *(Clupea harengus)* were used as bait.

Sex, state of maturity, morphometric and stomach content data were recorded for each swordfish boated. Representative food items were retained for mercury analysis. A number of tissue samples were removed from the swordfish and frozen for future analysis; tissue included: dorsal muscle (posterior), red muscle, abdominal wall muscle, heart, kidney, liver, gill, stomach, and vertebrae. Not all tissues were obtained for each fish.

Other pelagic species landed were treated in various ways, some being sampled in detail, as for swordfish, while only dorsal muscle tissue was retained from others. Total mercury content was determined, in duplicate, on homogenates of each tissue by the semiautomated flameless atomic absorption method of Armstrong and Uthe (1971) using a Perkin-Elmer model 403 atomic absorption spectrophotometer equipped with a Perkin-Elmer model 56 recorder. Sampling was performed by a Technicon Sampler II with a timer cam (30 samples per hour), sample wash ratio of 1:2, and a Technicon proportioning pump.

RESULTS

At least one tissue type has been analyzed from 210 swordfish *(X. gladius)*, and from 37 individuals of 13 other pelagic species (1 bluefin tuna, *Thunnus thynnus;* 1 white marlin, *Tetrapturus albidus;* 1 escolar, *Lepidocybium flavobrunneum;* 3 dolphin,

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[3] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Table 1.—Longline cruises yielding swordfish for mercury analysis.

Designation	Date	Number of sets	Area	Number of swordfish sampled
HS 104	23-27 July 1971	5	Georges	14
DG 1	23-31 Aug 1971	8	Banquereau and Grand Banks	63
DG 2	09-17 Sept 1971	6	Browns to Banquereau	73
DG 3	14-27 Oct 1971	6	Georges to Cape Charles	43
BIO 72-004	01-22 Mar 1971	8	Bahamas and Caribbean	17
FG 6	27-May-8 June 1972	12	Cape Hatteras to Sable	17
FG 7	17-28 June 1972	10	Cape Hatteras and Georges	16
FG 8	6-19 July 1972	14	South of Browns to Banquereau	4
FG 9	26 July-9 Aug 1972	13	South of Grand Banks	3
FG 10	14-31 Aug 1972	10	East of Grand Banks	4

Coryphaena hippurus; 1 long nose lancetfish, *Alepisaurus ferox;* 14 blue sharks, *Prionace glauca;* 4 sickle sharks, *Carcharhinus falciformis;* 1 dusky shark, *C. obscurus;* 2 tiger sharks, *Galeocerdo cuvieri;* 2 scalloped hammerhead sharks, *Sphyrna lewini;* 2 mako sharks, *Isurus oxyrinchus;* 1 porbeagle shark, *Lamna nasus;* and 4 unspecified lamnid sharks). The size range of the organisms and total mercury content of the dorsal muscle are shown in Table 2. Similar data for a single white shark *(Carcharodon carcharias)* obtained in an otter trawl, and two basking sharks *(Cetorhinus maximus)* taken from herring weirs in Passamaquoddy Bay, are also included in Table 2. In addition, mercury determinations were completed on 235 specimens of 12 species of fish taken from swordfish stomachs (Table 3).

DISCUSSION

The areas of capture can be divided into five parts; four divisions of the longline fishery and a fifth area to the south; the latter includes the Bahamas and eastern Caribbean. The captures in the northern divisions were made during four cruises in the period July-October 1971. Captures from the southern area were made in February and March 1972. The divisions of the swordfish longline fishery are shown in Figure 1, while the dates of fishing are given in Table 1.

Mercury levels found in swordfish tissue (dorsal muscle) were tabulated (Table 4) by localities and months.

Variation With Size

The slopes, correlation coefficients and "*t*" values obtained by application of the least squares fit for linear relation between fork length *(x)* and mercury content *(y)* are included in Table 4. It is apparent that there is a relationship, although considerable scatter exists.

Table 2.—Total mercury level (ppm) of dorsal muscle tissue of selected pelagic species.

Species	Number sampled	Fork length (range)	Total mercury Mean	Total mercury Range
		(cm)	*(ppm)*	*(ppm)*
Swordfish	210	74-247	1.15	0.05-4.90
Bluefin tuna	1	172	0.80	—
White marlin	1	187	1.34	—
Escolar	1	89	0.62	—
Dolphin	3	88-115	0.86	0.32-1.22
Lancet fish	1	122	0.08	—
Blue shark	14	69-190	0.70	0.40-1.17
Sickle shark	4	101-199	1.43	0.75-3.28
Dusky shark	1	120.1	2.08	—
Tiger shark	2	137-236	0.83	0.68-0.98
Scalloped hammerhead shark	2	147-177	3.64	2.40-4.89
Mako shark	2	151-159	1.16	1.02-1.30
Porbeagle shark	1	116	0.55	—
Mackerel shark	4	78-234	2.08	0.62-5.43
White shark	1	449	18.85	—
Basking shark	2	382	0.08	0.03-0.14

Table 3.—Total mercury (ppm) in food species taken from stomachs of swordfish.

Specimens	Number sampled	Total mercury content (ppm)	Dietary importance
Stromateidae (Butterfishes)			
Centrolophus niger (Black Ruff)	2	0.14	Occasional
Stomiatidae (Scaled dragonfishes)			
Stomias boa (Boa dragonfish)	1	0.17	Occasional
Myctophidae (Lanternfishes)	15	0.24	Important
Paralepididae (Barracudinas)	36	0.20	Important
Alepisauridae (Lancetfishes)			
Alepisaurus ferox (Longnose lancetfish)	2	0.41	Occasional
Nemichthyidae (Snipe eels)			
Nemichthys scolopaceus (Slender snipe eels)	4	0.24	Occasional
Gadidae (Cods)			
Merluccius bilinearis (Silver hake)	9	0.17	Locally important
Carangidae (Jacks)	2	0.13	Occasional
Scombridae (Mackerels)			
Scomber scombrus (Atlantic mackerel)	73	0.17	Bait
Scorpaenidae (Scorpionfishes)			
Sebastes marinus (Redfish)	14	0.34	Locally important
Monacanthidiae (Filefishes)	14	0.21	Occasional
Cephalopoda (Squids)			
Ilex illecebrosus (Shortfinned squids)	63	0.31	Important

Variation Between Sexes

Female swordfish predominated in all catches from the northern parts of the range in the northwest Atlantic; only 21 of the 193 fish caught in areas B, C, D, and E were males. Mercury levels of fish of the same size from the same area may differ between the sexes. The data for areas A, D, and E, which were the areas where most of the males were caught, are given in Table 5. The results are conflicting: In area A, males, on the average, contained higher levels than females of the same size; in area D, similar levels were found in both sexes for fish of the same average size; and in area E, similar levels were found but the males, on average, were smaller. Should the tendency for higher levels in males be confirmed, this may be due to a slower growth rate, and hence greater age at a given size.

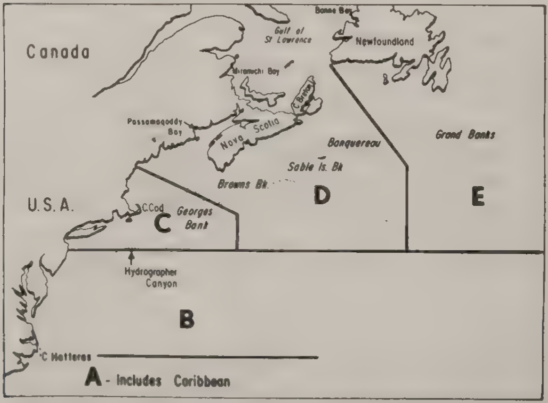

Figure 1.—Map of Northwest Atlantic Ocean showing areas of capture of swordfish used for mercury analysis.

Owing to the small sample sizes and the low relative numbers of males except in area A, the sexes were combined for subsequent discussion.

Variation with Time and Area

The localities sampled are listed chronologically in Table 4, with area C (Georges Bank) repeated since it was fished twice (July and October). Generally, the average total mercury content of the dorsal muscle decreased with time. The only exception was the average for fish from area E (Grand Banks), which was higher (1.42 ppm) than the average in any other northern area (B, C, or D) either earlier or later. The average size of fish from area E, at 167 cm fork length, was, however, considerably larger than that of fish from these other areas (Table 4). Evidence that the decrease in average mercury content was a result of time rather than locality (decreasing to the westward) is suggested by the reduction of the

Table 4.—Comparison of total mercury content (ppm) of dorsal muscle tissue with size of swordfish caught in different areas.

			Size		Total mercury content				
Fishing area	Month	Number of swordfish	Average (cm)	Range (cm)	Average (ppm)	Range (ppm)	Slope	Correlation coefficient	"*t*" for testing slope
A. Caribbean-Bahamas	Feb-March	17	159	(109-240)	2.02	(0.36-4.90)	0.00215	0.568	2.580*
C. Georges Bank	July	14	147	(85-188)	1.17	(0.16-2.08)	0.001312	0.777	4.275**
E. Grand Banks	Aug	39	167	(128-212)	1.42	(0.71-2.10)	0.007412	0.599	4.732**
D. Sable-Banquereau	Sept	94	145	(74-247)	1.07	(0.05-2.72)	0.006816	0.406	4.305**
C. Georges	Oct	25	142	(99-183)	0.88	(0.19-1.88)	0.005626	0.368	1.937*
B. Cape Hatteras-Hydrographer Canyon	Oct	21	129	(78-188)	0.57	(0.05-1.35)	0.009671	0.823	6.315**

*Significant at 0.90 level.
**Significant at 0.95 level.

average mercury level in area C between the July and October samples for fish of essentially the same size. Swordfish from area B (Cape Hatteras to Hydrographer Canyon) were considerably smaller (average 129 cm) than fish taken in other areas. This size difference may also account, at least in part, for the lowest average mercury level (0.57 ppm) being encountered in area B.

Variation of Mercury Content Between Tissues

The total mercury content of the various tissues sampled from swordfish is shown in Table 6. Generally red muscle, liver, kidney, and heart contained higher levels of total mercury than dorsal muscle while other tissues contained less.

The mercury content of the various tissues was examined by area and time of capture in the same manner as for the dorsal muscle samples. When these data were expressed (Table 7) as proportion (percentages) of the dorsal muscle values, most tissues showed relatively little variation, with the exception of the liver and kidney values. The mercury content of the latter two tissues ranged from about the same as that of the dorsal muscle (areas C and D) to approximately twice that level (areas A, B, and E). The elevated average levels in kidney and liver from area E were due to one large fish which had a mercury content in these tissues of over three times that of the dorsal muscle. The elevated levels for areas A and B are shown by all specimens, however, and appear to be characteristic. These elevated levels suggest that mercury was either being more rapidly eliminated from the body in areas A and B, or likely was being taken up in greater quantities from the environment. The average mercury level (Table 4) in dorsal muscle from area A was considerably higher (2.02 ppm) than from any other area, but that from area B was the lowest (0.857 ppm). However, it has already been noted that area B fish were much smaller than fish from other areas and Table 4 also indicates that the relation between size and mercury content (slope of regression line 0.009671) in area B was steeper than elsewhere, so that larger fish would presumably have shown high levels similar to those from area A.

Mercury Levels in Food Items

Food organisms collected from swordfish stomachs and analyzed for the total mercury content (Table 3) all show fairly high values (average 0.14-0.3 ppm for each species); although the possible contribution of mercury from the digestive juices of the predator cannot be ignored. The relatively high mercury content of redfish (0.34 ppm) may be of significance in considering the high values in the liver and kidney obtained from one large swordfish (212 cm) caught in area E (Grand Banks). Redfish form a

Table 5.—Comparison of total mercury content (ppm) of dorsal muscle tissue from swordfish by sex and by area.

Area	Month	Number and sex	Fork length Mean (cm)	Fork length Range (cm)	Total mercury content Mean (ppm)	Total mercury content Range (ppm)	Slope	Correlation coefficient	"*t*" for testing slope
E. Grand Banks	Aug	7 Males	152	(136-178)	1.39	(0.7-1.9)	0.02398	0.757	2.589*
Grand Banks	Aug	32 Females	170	(128-212)	1.42	(0.9-2.1)	0.006749	0.637	4.604**
D. Sable-Banquereau	Sept	9 Males	148	(127-170)	1.09	(0.7-1.4)	0.007265	0.543	1.713
Sable-Banquereau	Sept	65 Females	144	(74-247)	1.07	(0.1-1.8)	0.007269	0.417	3.649**
A. Bahamas-Caribbean	Feb-Mar	9 Males	149	(109-163)	2.21	(0.36-4.90)	0.094809	0.543	1.709
Bahamas-Caribbean	Feb-Mar	5 Females	146	(110-224)	1.58	(0.41-4.36)	0.03370	0.990	12.136**

*Significant at 0.90 level.
**Significant at 0.95 level.

major proportion of the diet of swordfish in that particular area (Scott and Tibbo, 1974). This is especially true for fish larger than 160 cm, possibly because such fish feed deeper (Beckett, 1973). Squid, the other relatively mercury-rich food species, also appear to be more important in the diet of swordfish from area E than from elsewhere, with the exception of the adjacent part of area D (Scott and Tibbo, 1974).

Mercury analyses are currently not available for stomach contents of swordfish taken from area A, while for area B data are insufficient for comment.

Other Species

The mercury content of the dorsal muscle of 12 other pelagic species (Table 2) was all high with the

Table 6.—Total mercury content (ppm) of selected swordfish tissues.

Tissue	Number of samples	Total mercury content Average (ppm)	Total mercury content Range (ppm)
Dorsal muscle	210	1.15	0.05-4.90
Red muscle	32	1.59	0.12-5.36
Abdominal muscle	80	1.10	0.05-4.85
Liver	33	3.00	0.07-15.10
Kidney	33	1.91	0.09-8.63
Heart	33	1.64	0.17-5.38
Brain	22	0.90	0.11-1.54
Gill	43	0.43	0.11-1.54
Vertebral disc	43	0.20	0.03-0.57
Stomach	107	0.50	0.06-1.23

Table 7.—Total mercury content (ppm) of selected tissues as percentage of total mercury content of the dorsal muscle tissues. (Number of samples given in parentheses.)

Tissue	A Caribbean-Bahamas	B Cape Hatteras-Hudson Canyon	C Georges July	C Georges Oct.	D Browns to Banquereau	E Grand Banks
Red muscle	117 (14)	139 (3)	117 (3)	104 (2)	112 (7)	106 (3)
Abdominal muscle	87 (15)	87 (3)	94 (4)	96 (3)	77 (25)	74 (30)
Liver	263 (15)	240 (2)	105 (3)	86 (2)	106 (7)	175 (3)
Kidney	145 (15)	148 (3)	82 (3)	58 (2)	98 (7)	208 (3)
Heart	116 (15)	154 (3)	114 (3)	97 (2)	130 (7)	117 (3)
Brain	62 (15)	58 (3)	—	—	—	—
Gill	33 (15)	58 (1)	29 (15)	20 (2)	30 (7)	28 (3)
Vertebral disc	14 (15)	15 (2)	18 (14)	5 (2)	14 (7)	12 (3)
Stomach	—	—	52 (10)	—	43 (64)	40 (34)

maximum 18.85 ppm for a white shark. The only exceptions were a lancet fish (0.08 ppm) and two basking sharks (0.03 and 0.14 ppm). The data are too few for any deductions other than that the general tendency is for higher levels to occur in species that eat large fish, although, on this basis, the dusky and scalloped hammerhead sharks may be excessively high. These shark specimens were captured in area A, however, and may be showing elevated levels similar to swordfish from that area.

CONCLUSIONS

The decrease in mercury content of dorsal muscle with time for swordfish in the northern part of their range, and the high levels in excretory tissues from fish in the southern warmer areas, suggest that the uptake of mercury may change during the annual migratory cycle. Further data on food species, however, are necessary to confirm whether swordfish are ingesting higher levels of mercury in their prey during the winter when they occur in the Caribbean and southern Gulf Stream, and losing the mercury when they migrate to the north during the summer. The high mercury levels in the kidney and liver tissues of one fish taken from area E (Grand Banks), which contrast with the general trend in the northern areas, may indicate heavy feeding on redfish, a species with a high mercury content.

SUMMARY

Total mercury contents were determined for at least one tissue from each of 210 swordfish, 40 individuals of 15 other pelagic species and for the body musculature of 235 individuals of 12 prey species.

Dorsal muscle mercury levels for swordfish of 74-247 cm fork length ranged from 0.05 to 4.90 ppm (mean 1.15 ppm).

Mercury content of the dorsal muscle of swordfish showed a linear relationship with size.

The mercury content of the dorsal muscle may vary with sex, males having a higher level, possibly being correlated with the older age for a given fish size.

The mercury content appeared to decrease with time for fish in the northern part of the range.

Mercury levels in red muscle, liver, kidney, and heart exceeded those of the dorsal musculature, while those in other tissues were less.

Mercury uptake and/or excretion was higher in the Caribbean and Gulf Stream, south of Cape Hatteras, than to the north and east.

Some increase in mercury levels may occur near the Grand Banks where major food items (redfish and squid) were relatively rich in this element.

The mercury content of other pelagic species examined ranged from 0.03 ppm for a basking shark to 18.85 ppm in a white shark.

ACKNOWLEDGMENTS

Thanks are due to members of the Fish Contaminants Division of the Halifax Laboratory for carrying out the mercury analyses, and to the staff at the Biological Station, St. Andrews, especially to those members of the Pelagic Programme who collected much of the material, and to members of the Statistical Group for their assistance in examining the data. Grateful acknowledgement is made of the use of the Canadian Hydrographic vessel *Dawson* for the Caribbean cruise.

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Mercury in Several Species of Billfishes Taken Off Hawaii and Southern California

RICHARD S. SHOMURA[1] and WILLIAM L. CRAIG[2]

ABSTRACT

The results of analyses of the mercury content of 37 blue marlin, *Makaira nigricans*, 56 striped marlin, *Tetrapturus audax*, and 3 swordfish, *Xiphias gladius*, are presented.

The levels of total mercury found in white muscle of blue marlin caught in Hawaiian waters ranged from 0.19 ppm to 7.86 ppm; fish specimens ranged in total weight from 96 pounds (43.5 kg) to 906 pounds (410.9 kg). A trend of increasing mercury level with increasing size of fish was noted. The mercury content in the livers of 26 blue marlin specimens examined ranged from 0.13 ppm to 29.55 ppm; there was no apparent trend noted between mercury content in the liver and size of fish.

Striped marlin from Hawaii and southern California showed a range of mercury levels in white muscle of 0.09-1.09 ppm for the 14 Hawaii samples examined and 0.03-2.1 ppm for the 42 California samples examined. The range in size of fish was 56-139 pounds (25.4-63.0 kg) and 109-231 pounds (49.4-104.8 kg) for the Hawaii and California samples, respectively. From the wide spread of mercury levels encountered in striped marlin, a trend of mercury level with size of fish could not be easily detected. Livers of nine specimens from the Hawaii catch were analyzed; mercury levels ranged from 0.05 ppm to 1.53 ppm.

Three swordfish weighing 6 pounds (2.7 kg), 100 pounds (45.4 kg), and an estimated 500 pounds (226.8 kg) contained mercury levels in white muscle of 0.04, 1.71, and 2.10 ppm, respectively.

In early December 1970 the news media stunned the nation, particularly the fishing industry, with the release of stories that some canned tuna and swordfish steaks contained mercury in excess of the Food and Drug Administration (FDA) interim guideline of 0.5 ppm (Bernstein, 1970; Fleming, 1970; Los Angeles Times, 1970; Coffey, 1971). Prior to State University of New York Professor Bruce McDuffie's discovery that mercury levels in two cans of tuna exceeded the FDA guideline, the problem of mercury in fishes was thought to be localized and confined to freshwater fish species. The high levels of mercury in freshwater fishes were attributed to dumping of waste products into waterways.

A review of the literature undertaken at the time of the announcement of mercury in tuna and swordfish revealed a wealth of information related to mercury and its toxic properties; references were primarily of incidents occurring in Japan and Sweden. Despite the wide range of available information, there was a conspicuous lack of data related to mercury levels in living organisms in the marine biosphere. For this reason the National Marine Fisheries Service embarked upon an extensive program early in 1971 to collect tissue samples of marine and estuarine fishes and invertebrates for analysis of mercury and other heavy metals (Commercial Fisheries Review, 1971).

Primarily because of their recreational value, the California Department of Fish and Game collected samples of striped marlin, *Tetrapturus audax*, and albacore, *Thunnus alalunga*, for mercury analysis during the summer of 1971.

Our purpose in this paper is to provide the results of analysis for total mercury content in samples of striped marlin, blue marlin, *Makaira nigricans*, and swordfish, *Xiphias gladius*. We will simply present these data with some brief comments of the more notable features. It is not our intention to review the instances of mercury poisoning, the legal aspects of the mercury guideline, nor the issue of natural versus pollution-caused heavy metal contamination.

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MATERIALS AND METHODS

Of the 56 striped marlin sampled, 42 were caught off southern California, while the remaining 14 were from Hawaiian waters. All of the 37 blue marlin and 2 of the 3 swordfish were from Hawaiian waters. One small (2.7 kg) swordfish was caught with longline gear in the central equatorial Pacific. The recreational fishery provided all the California samples; data and tissues were collected either at the weighing facilities of the Balboa Angling Club or the Marlin Club of San Diego. The Hawaii samples consisted of fish caught by the commercial longline fleet and by the troll sport fishery. The commercial catch was sampled at the Honolulu fish auction, while the sport catch was from fish caught during the 1971 Hawaiian International Billfish Tournament held at Kailua-Kona, Hawaii.

With the exception of the small swordfish which was preserved in Formalin,[3] all of the samples were collected from fresh, unfrozen specimens. From ½ to 1 pound (0.23 to 0.45 kg) of white muscle tissue was excised from each fish. In the California striped marlin samples, the tissue was removed from the dorsal loin above the left pectoral fin. Nearly all the Hawaii samples came from near the caudal area because this portion is usually discarded after a buyer has purchased the fish from the auction market. In all cases the tissue sample was cleaned of skin and bone, wrapped in inert aluminum foil, labeled, and then frozen as soon as possible. After the samples had been collected they were packed in Dry Ice and shipped to the analytical laboratories by air. Liver tissue from 4 Hawaiian striped marlin and 26 blue marlin also were collected for comparative analysis.

The Hawaii samples were analyzed at a National Marine Fisheries Service Laboratory while those from California were done by a Department of Fish and Game Laboratory. In 17 of the California striped marlin sampled, muscle tissues were sent to each of the analytical laboratories.

Similar laboratory procedures were followed in all cases; this consisting basically of the semiautomatic, cold vapor, atomic absorption technique (Uthe, Armstrong, and Stainton, 1970). This technique requires a lengthy process of homogenizing, digesting, etc., prior to obtaining a total mercury value from the atomic absorption apparatus.

RESULTS

Striped Marlin

Our study covered a relatively wide size range for this species; the smallest weighed 56 pounds (25.4 kg) and the largest 231.5 pounds (105.0 kg). Generally, the larger striped marlin were from southern California while the smaller fish were from Hawaii. Total mercury values averaged 0.8 ppm and ranged from a low of 0.03 ppm in a 135-pound (61.2 kg) fish to 2.1 ppm in a 231.5 pound (105.0 kg) fish, the largest sampled (Fig. 1). Seventy percent or 42 fish exceeded the FDA guideline of 0.5 ppm. A trend line calculated for these data indicates a general increase in total mercury with increasing size of fish. However, as Figure 1 indicates, the increase is erratic and impossible to predict. While the largest fish resulted in the highest mercury content, it is well to note that the second largest, a 218 pounder (99.0 kg), was tested at 0.29 ppm, a figure well below the FDA guideline.

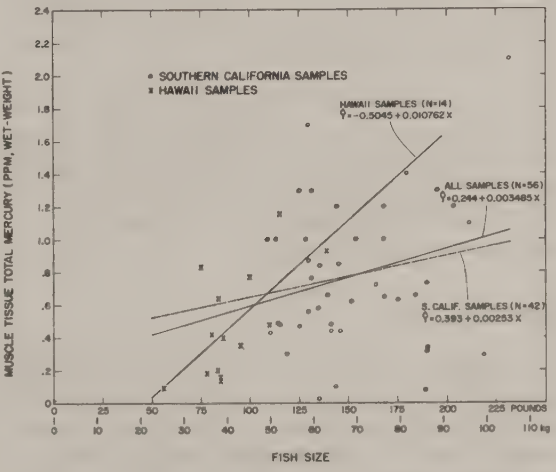

Figure 1.—Relationship between total mercury (ppm) in white muscle tissue and size of fish of striped marlin from southern California and Hawaiian waters.

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[3] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Table 1.—Comparison of mercury levels in striped marlin tissues analyzed by two laboratories.

	Laboratory no. 1	Laboratory no. 2
Mean HG	0.77 ppm	0.84 ppm
Standard deviation	0.35	0.50
>0.5 ppm	15 fish	12 fish
<0.5 ppm	2 fish	5 fish
High value	1.0	2.1
Low value	0.4	0.1

Some of this variability may be due to analytical technique for it should be remembered that different laboratories provided the analytical data. While analytical methods were being developed there appeared to be considerable variability between laboratories, although the reproducibility within a given laboratory was very high. Our data from the 17 samples that were run by two of the laboratories tend to bear out this feature. Extreme values were repeatable within both laboratories, but there were differences between the laboratories. These differences are illustrated best in tabular form (Table 1).

Looking at individual samples, one laboratory was not consistently high or low and no two values for a particular fish were identical. In several instances one laboratory reported mercury values over the FDA guideline while the other was below. Again, neither laboratory was consistent in this respect.

The livers from four Hawaiian fish also were analyzed for total mercury. Mercury levels of the three small fish (81, 83, and 96 pounds—36.7, 37.6, and 43.5 kg, respectively) were all less than 0.2 ppm, but the single large fish of 139 pounds (63.0 kg) had a value of 1.54 ppm.

Blue Marlin

The mercury data for all the blue marlin were from fish taken in Hawaiian waters. Total mercury levels of white muscle tissue in this species ranged from 0.7 ppm to 7.86 ppm in fish weighing between 96 and 906 pounds (43.5 and 410.9 kg). The results are presented in Figure 2. When compared to striped marlin, the mercury levels in blue marlin were much higher. Only 7 of the 37 blue marlin tested had levels less than 1.0 ppm, while for striped marlin 45 of the 56 fish tested were below that level. The highest value recorded for blue marlin was 7.86 ppm which, surprisingly, was not from the largest specimen, but from a fish weighing 211 pounds (95.7 kg).

As with striped marlin, the range in mercury level for blue marlin is large. However, there appeared to be an indication of a positive relationship between mercury level and fish size when a regression was fitted to the data (Fig. 2). Again, this relationship shows a wide variation around the regression. We would find it difficult to use these data for predicting mercury content in a given specimen.

For comparative purposes we have plotted the linear regression presented by Rivers, Pearson, and Schultz (1972) for blue marlin samples from Hawaiian waters. Since many of the same fish tested by Rivers et al. (1972) were included in our study, we can only conclude that the marked difference in regressions is due to differences in analytical technique. There is agreement, however, that the levels of mercury in blue marlin are considerably higher than the FDA guideline.

The livers of 26 blue marlin also were analyzed for total mercury. The values ranged from 0.13 ppm

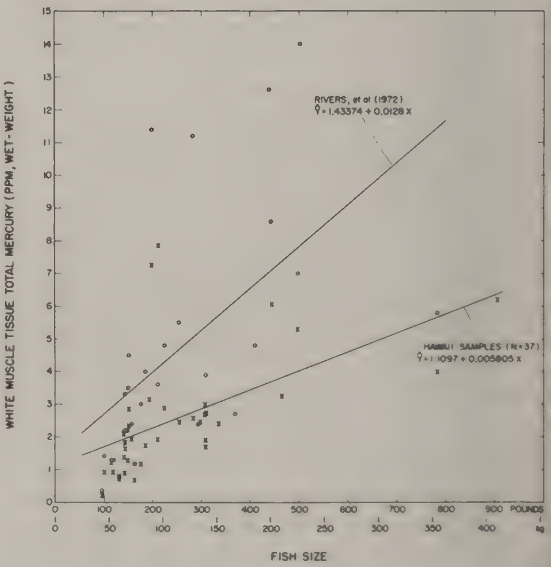

Figure 2.—Relationship between total mercury (ppm) in white muscle tissue and size of fish of blue marlin from Hawaiian waters. (o denotes Rivers et al. (1972) samples, x denotes our samples.)

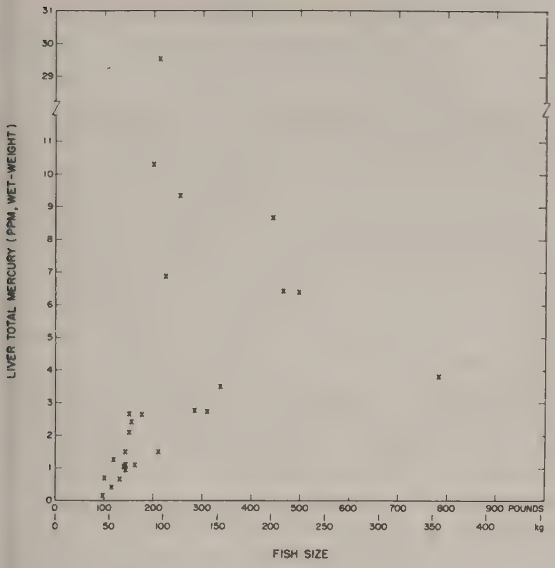

Figure 3.—Relationship between total mercury (ppm) in liver tissue and size of fish of blue marlin from Hawaiian waters.

to a phenomenal 29.55 ppm (Fig. 3). Based upon published literature the latter may be the highest level of total mercury reported for any fish. Coincidentally, this high value was from the same 211-pound (95.7-kg) fish whose white muscle tissue contained the extremely high level of 7.86 ppm total mercury. There does not, however, appear to be a consistent relationship between total mercury content in livers and the content in white muscle tissues.

Swordfish

Only the muscle tissue from three swordfish was analyzed for total mercury. The mercury level in a juvenile swordfish weighing 6 pounds (2.7 kg), which had been preserved in Formalin, measured 0.04 ppm. The analyses from two other fresh specimens from Hawaiian waters weighing 100 pounds (45.4 kg) and 500 pounds (226.8 kg), were 1.7 and 2.1 ppm total mercury, respectively.

DISCUSSION

Results of this investigation may be considered a contribution to the fund of information pertaining to this controversial subject. Confirmation of high mercury levels in billfishes and the relationship of mercury to size, sex, or other variables will require further study.

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Summer Concentration of White Marlin, *Tetrapturus albidus*, West of the Strait of Gibraltar[1]

C. RICHARD ROBINS[2]

ABSTRACT

Examination of fish catches landed in August 1961 at various ports in southern Portugal and the adjacent coast of Spain demonstrated that the white marlin, *Tetrapturus albidus*, concentrated in these waters during this month. The coincident absence of white marlin in landings at Sicily make it likely that the species does not enter the Mediterranean in any numbers at least at this season.

August concentrations of white marlin elsewhere in the Atlantic are discussed along with the implications of the coincident timing of them on population structure of the species.

Morphometric data are presented on 57 specimens from this eastern Atlantic population to facilitate future comparison with specimens from elsewhere in the range of the species.

In 1961, the writer visited Italy, Spain, and Portugal to study 95 istiophorid fishes that had been purchased from fishermen and stored in large freezers for that purpose. Arrangements for the purchase and storage of the fish had been made by the late John K. Howard during his travels through the region in the summers of 1960 and 1961.

The main goal of the project was to determine the status of the Mediterranean spearfish, *Tetrapturus belone* Rafinesque, and that result was published by Robins and de Sylva (1963) based on thirty-five specimens, all from Sicily. Equal attention, however, was devoted to other istiophorids. Of the remaining 60 specimens, 57 were white marlin, *Tetrapturus albidus* Poey, an amphi-Atlantic species whose biology remains poorly known.

Except for three specimens, one caught 14 September, and two on 5 October, all specimens were collected between 31 July and 24 August 1961 off the southern coasts of Portugal and Spain and off northwestern Morocco. The 1961 season was said to be especially good off Olhão, Portugal. The species is said to be especially common in this region in August, which coincides with the time of postspawning feeding concentrations elsewhere. Between Ocean City, Maryland and Atlantic City, New Jersey, the peak season extends from the end of the second week of July to about the last week in August (de Sylva and Davis, 1963: tables 2 and 3); off the Mississippi Delta, in the Gulf of Mexico a large concentration occurs in July and August (Gibbs, 1958: Figure 1); and off La Guaira, Venezuela, the peak is also in August but large numbers occur through September and into October (Pérez de Armas, 1959, and unpublished data courtesy of Donald P. de Sylva).

With four, nearly simultaneous, postspawning concentrations known to occur in distant parts of the Atlantic Ocean, the population structure of this giant pelagic predator obviously is complex. Mather (1968) discusses the results of a tagging program in the western Atlantic which had then yielded 34 returns out of nearly 4,000 tagged fish. He comments on the three western Atlantic populations which he terms the northwestern Atlantic stock, Gulf stock, and Venezuelan stock. To facilitate morphometric comparison of the populations, and because these large fishes are not preserved and thus are unavailable to future researchers, the data obtained from the eastern Atlantic specimens are presented here following the format of Robins and de Sylva (1961, 1963). Certain aspects of the biology are discussed.

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STATUS OF THE WHITE MARLIN IN THE EASTERN ATLANTIC

Robins and de Sylva (1963: 89-90) reviewed the synonymy of *Tetrapturus belone* and (p. 97) noted that all literature records of that species from outside the Mediterranean Sea either apply to other species or are without a verifiable basis. Sassi (1846) recorded the first white marlin from the eastern Atlantic (from the Mediterranean Sea) under the name *Tetrapturus belone*. Canestrini (1861) recognized that Sassi's specimen in Genoa was not *belone* and made it the type of his well described and illustrated species, *Tetrapturus lessonae*. This description, in fact, postdates Poey's (1860) description of *Tetrapturus albidus* from Cuba, by only one year. Since then Eastern Atlantic records of *albidus* occur under *Makaira nigricans, Tetrapturus belone, T. lessonae* in various combinations. Robins and de Sylva (1961: 97) referred the record of *T. belone* by Legendre (1928) to *albidus* and discuss other probable records. Gonçalves (1942: 54-55) was perhaps the first to suggest that *albidus* occurred in Portugal's waters. La Monte (1955: 331-332 first referred *lessonae* to the synonymy of *albidus* and from this date *albidus* begins to appear in records of Eastern Atlantic and Mediterranean specimens (Robins and de Sylva, 1961; Tortonese, 1961; Rodriguez-Roda and Howard, 1962). Ueyanagi et al. (1970) summarize longline catches of white marlin throughout the tropical and temperate Atlantic. A review of the literature relative to *T. albidus* and other "istiophorids" in the eastern Atlantic is being prepared by Donald P. de Sylva.

MATERIAL EXAMINED

The 57 specimens identified as *Tetrapturus albidus* were given field numbers coded EATL-1 to 57. Those numbered EATL-1 to 38 were studied at Olhão, Portugal, the remaining 19 at Cadiz, Spain. Most of the Cadiz specimens were caught on fishing lines operated by swordfish fishermen in the Strait of Gibraltar and to the west along the southern coast of Portugal and Spain and the northern coast of Morocco. Six were caught in tuna traps (almadrabas) near Huelva, Spain (west of Gibraltar) and La Linea, Spain (immediately east of Gibraltar in the Alboran Sea). The locations and dates of capture of numbers 39-57 were noted by Rodriguez-Roda and Howard (1961: table 1) and these data are not repeated here.

The 38 specimens examined at Olhão, Portugal, were mostly captured in traps (including Livramento, Medo dos Cascas, and Barril) off Tavira, Portugal as follows (all dates in 1961): 6 Aug.: EATL-1, 4, 8, 13, 14, 15, 16, 19, 31, 35, 37; 10 Aug.: EATL-5; 12 Aug.: EATL-17; 17 Aug.: EATL-6, 7, 10, 11; 21 Aug.: EATL-25, 26, 28; 22 Aug.: EATL-22, 36, 38; 23 Aug.: EATL-21, 23, 24, 29, 32, 34. The remaining eight fish were hooked as follows: off Tavira, Portugal; 31 July: EATL-3, 33; 1 Aug.: EATL-9; 16 Aug.: EATL-2. Off Olhão, Portugal: 9 Aug.: EATL-18; 10 Aug.: EATL-20. Off Fuzeta (near Olhão), Portugal: 21 Aug.: EATL-30; 23 Aug.: EATL-27.

Frank J. Mather, III has brought to my attention two white marlin, 2,000 cm and 1,725 cm body length, which were caught 6 October 1969, by longline off Cadiz, Spain. Sex was not determined. The larger was estimated to weigh 65-70 kg. Although not examined by the present writer, these records are included here for sake of completeness of information on the subject.

Explanation of the Tables

The format of Appendix Tables 1 and 2 follows that of Robins and de Sylva (1961, 1963). Numbers in parentheses (first column) refer to the numbered definitions of Rivas (1956). Field numbers are as noted above. Specimens are arranged by increasing body length and the field numbers therefore are not in sequence.

The following abbreviations are used.

D_1 = spinous or first dorsal fin
D_2 = second dorsal fin
C = caudal fin
A_1 = first anal fin
A_2 = second anal fin
P_1 = pectoral fin
P_2 = pelvic fin
orig. = origin (in reference to fins)
c.p. = caudal peduncle

Sex

Sex was determined and recorded for all specimens except EATL-37. Only five of the 57 specimens were males (Fig. 1). They are EATL-7, 10, 11, 33, 34, all caught in the Tavira-Olhão area, four of them in traps (three on 17 August, one on 23 August), one on hook and line (31 July). All are small, their weights being 35, 25, 27, 25, 25 kilo-

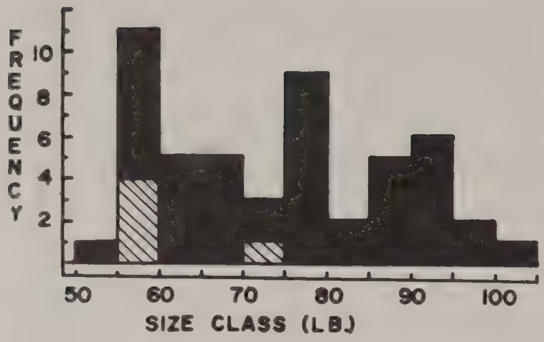

Figure 1.—Weight-frequency histogram of white marlin, *Tetrapturus albidus,* from the eastern North Atlantic Ocean. Solid color = females, cross-hatching = males.

grams respectively. None was in ripe or near ripe condition. All females were in a refractory state with no developed eggs except that EATL-6 had relatively large ovaries with very small eggs. However, it, too, was nowhere near reproductive state.

These data agree with the suggestion that the white marlin concentrations are postspawning affairs. Also, Ueyanagi et al. (1970) demonstrate convincingly that white marlin spawn early in the summer and they further suggest that the postspawning feeding migration to temperate waters then occurs. The Japanese have done little work in the eastern Atlantic north of lat. 30°N and east of long. 30°W. Why there should be a preponderance of females is unknown but de Sylva and Davis (1963: 87) also noted a significantly large percentage of female marlins in the Middle American Bight in 1959 though not in 1960. There is nothing in our limited data nor in the much larger samples of de Sylva and Davis to suggest a time difference in the peak abundance of males and females.

Food

All stomachs were examined but the stomach acid of marlins is strong and the time from trap to freezer uncertain. Also marlins taken on hooks frequently void the contents of their stomach. In any event only well digested remains, some of it fish in origin, were found.

Weight

Weight in pounds is given for each specimen in Appendix Tables 1 and 2 with equivalent weights in kilograms in Appendix Table 1. These weights are of the frozen or partly thawed fish but they probably do not vary in any meaningful way from the original weights. To facilitate comparison with the data of de Sylva and Davis (1963: Figures 4 and 5) a histogram of weights in 5-lb (2.27-kg) units is presented in Figure 1.

Although data are few the first peak in the 55-59 lb (24.9-26.8-kg) range agrees remarkably with the weight frequency data for American Bight specimens. There are more large fish off Gibraltar and the lower peaks at 75-79 (34.0-35.8-kg) and 95-99 lb (43.1-44.9-kg) probably represent successive year classes. If so, the data suggest that older year classes of white marlin along the Atlantic coast of the United States do not participate in the migration or that they are fished out in that population. A wider range in weights is seen in white marlins in southern Florida (personal observations) which might support the first of these suggestions but more likely indicates that the large Florida and Bahamas fishes are not part of the population that congregates in the Middle American Bight. Mather's (1968) chart of migration trends based on 34 tag returns shows the pivotal nature of the Florida-Bahama region relative to the three stocks and that at least some marlin from this area participate in the summer concentration off the Mississippi Delta. Possibly fishes of the Gulf and northwestern Atlantic stocks pass through the Straits of Florida. Determination of minor morphometric differences between these stocks would be invaluable in analyzing the catch in the Straits of Florida but data available are inadequate and no such study has yet been undertaken. The Venezuela stock may be confined to northern South America.

Population Structure

No clear picture yet emerges with regard to the population structure of the white marlin. Specimens from the eastern and western Atlantic are not meristically distinct (Table 1). The detailed analysis of the Atlantic longline operations of the Japanese fishing fleet by Ueyanagi et al. (1970) shows a summer peak in the western Atlantic consistent with the late summer concentrations off Louisiana and Maryland-New Jersey. Their data however give no real indication of a Venezuelan concentration and they have virtually no data on the species from the eastern Atlantic north of lat. 25° or 30°N. Their data definitely indicate a dense population ong the eastern coast of Brazil from Pernambuco São Paulo in southern spring and summer (Sepmber to March). No doubt it is the Japanese data n which Mather (1971) bases his remarks about razilian and mid-ocean concentrations. Japanese shing effort is far from consistent (Ueyanagi et al. 970, fig. 17) and the hook rate data are difficult to valuate. The tendency to set many hooks in good shing areas obscures the density by lowering the ook rate index. Similarly the grouping of data on aturity by quarters obscures the early summer pawning peak since it is divided between two quarers. Actually it is unclear how widespread is the arly summer spawning peak. In the western Atlanic, data based on gonad examination and appearnce of larvae (de Sylva, pers. comm.) indicate that pawning is largely complete by May at which time nigration is already under way.

Mather et al. (1972) review the Japanese data in greater detail and summarize information gained rom the Cooperative Game Fish Tagging Program n the western Atlantic. They note that one North Atlantic population concentrates along the middle Atlantic coast of the United States in the summer nd moves to the north coast of South America in winter. They also record the separate summer concentration in the Northern Gulf of Mexico but because it shares a northern South American winterng ground the relationships of the two was said to be uncertain. So too was the origin of the population that occurs in summer off Venezuela. The white marlin in the South Atlantic was clearly recognized by these authors as separate from those in the north. No information was given for the northeastern Atlantic.

The migratory path of the white marlin to and from the approaches to Gibraltar is unknown but data published by Ueyanagi et al. (1970 appendix, figs. 2 j, k, l) suggest progressive movement south along Africa to about lat. 5° N.

Clearly an intensive program of research is needed on this important food and game species.

ACKNOWLEDGMENTS

Many persons have aided the billfish research program at the School of Marine and Atmospheric Science. Those previously acknowledged by Robins and de Sylva (1961: 384-384) and Rodriguez-Roda and Howard (1963) are omitted here. The late John K. Howard made all the arrangements for the Mediterranean work and subsidized much of its cost. The writer's travel to Europe and the purchase of some of the material was supported by the Maytag Chair of Ichthyology. Analysis of the data and preparation of the paper is part of a program on oceanic fishes supported by the National Science Foundation (NSF-GB-7015x, C. Richard Robins, principal investigator). Shari Lou Buxton processed the data for the tables. Donald P. de Sylva reviewed the manuscript and made available data on the white marlin in the western Atlantic. Finally, I especially thank Rui Monteiro and Julio Rodriguez-Roda, Laboratorio del Instituto de Investigaciones Pesqueras, Cadiz, Spain, for aiding the writer in many ways during his work at Olhão, Portugal and Cadiz, Spain.

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Table 1.—Fin-ray counts of western[1] and eastern Atlantic white marlin, *Tetrapturus albidus*.

	Dorsal Spines								D_2 Rays			Anal Spines						A_2 Rays			P_1 Rays [2]					
	38	39	40	41	42	43	44	45	5	6	7	13	14	15	16	17	18	5	6	7	17	18	19	20	21	22
W. Atl.	1	3	8	10	11	9	—	—	20	21	1	4	18	18	5	—	—	2	41	—	1	2	6	23	9	—
E. Atl.	—	1	7	16	19	8	5	1	26	30	—	2	9	28	12	3	2	5	50	1	—	2	10	30	13	1

[1] Data from Robins and de Sylva (1961: Table 1)
[2] Only the left pectoral fin was counted.

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Appendix Table 1.—Morphometric data for 56 of 57 specimens of *Tetrapturus albidus* from the eastern North Atlantic. (Specimen 53, a female, 90 lb, was without its head and thus no measurements were recorded.) Measurements (in millimeters) are as defined by Rivas (1956) unless otherwise indicated. Numbers in parentheses refer to the numbered definitions of Rivas; see text for explanation of abbreviations.

Specimen Number	52	38	34	33	57	11	39	42	50	51	46	20	22	29	1	4	25	31	10
Body length (1)	1,600	1,610	1,620	1,628	1,640	1,640	1,662	1,670	1,675	1,685	1,700	1,705	1,705	1,710	1,715	1,730	1,734	1,745	1,745
First predorsal length (3)	378	366	372	374	364	391	380	405	385	410	400	390	406	376	402	410	410	397	400
Second predorsal length (4)	1,300	1,330	1,305	1,330	1,340	1,345	1,340	1,375	1,365	1,395	1,385	1,395	1,400	1,365	1,360	1,415	1,421	1,443	1,415
Prepectoral length (5)	415	422	430	430	422	450	423	450	428	445	458	448	454	430	440	450	462	444	475
Prepelvic length (6)	451	453	459	460	445	472	455	472	467	478	474	490	486	476	475	475	492	472	505
First preanal length (7)	962	960	977	995	970	995	980	1,020	1,020	995	1,015	1,040	1,018	1,020	1,010	1,040	1,035	1,010	1,055
Second preanal length (8)	1,265	1,300	1,295	1,308	1,300	1,310	1,305	1,335	1,330	1,330	1,348	1,350	1,360	1,350	1,352	1,370	1,390	1,385	1,400
Orig. D_1 to orig. P_1 (9)	200	206	215	204	210	220	210	236	206	216	220	220	215	212	198	216	225	218	215
Orig. D_1 to orig. P_2 (10)	255	270	262	270	272	282	285	295	284	284	285	284	275	284	275	275	290	275	276
Orig. D_2 to orig. A_2 (11)	150	156	145	146	150	146	145	168	155	157	158	155	154	165	154	165	165	157	142
Tip mandible to anus	891	882	901	930	885	920	906	935	945	935	948	952	942	955	920	975	950	952	970
Orig. P_2 to nape (13)	255	264	274	287	266	290	272	280	285	287	295	286	276	285	270	274	288	275	285
Greatest body depth (14)	260	265	276	275	275	275	273	309	280	276	286	280	268	287	276	280	286	280	266
Depth at orig. D_1 (15)	245	250	258	262	262	275	263	290	280	266	286	270	260	280	276	270	268	261	266
Depth at orig. A_1 (16)	205	224	212	216	215	220	210	245	212	220	215	221	220	228	222	235	236	231	218
Least depth c.p. (17)	65	63	64	63	63	65	61	70	65	66	62	72	66	65	69	74	71	65	65
Width at P_1 base (18)	125	122	135	124	120	120	128	140	125	130	125	135	120	130	130	144	138	129	122
Width at A_1 orig. (19)	125	131	130	123	130	132	126	155	125	144	130	128	125	145	138	140	142	144	130
Width at A_2 orig. (20)	98	110	—	100	102	104	110	120	102	110	104	101	108	115	117	128	112	104	94
Width c.p. (in front of keels)	50	53	60	51	50	44	50	57	56	50	52	51	49	57	63	63	55	53	44
Length upper keel (22)	58	53	61	66	57	59	57	58	53	57	66	69	66	66	58	62	60	57	68
Length lower keel (23)	54	43	53	60	54	55	58	54	52	50	54	55	55	56	56	57	57	55	58
Head length (24)	417	410	420	420	415	420	416	442	422	438	434	437	445	423	440	446	452	435	447
Snout length (25)	208	196	200	205	208	195	202	220	200	205	205	207	219	195	217	220	212	210	216
Bill length (26)	—	485	470	475	405	—	495	—	465	—	—	475	522	515	515	485	512	484	465
Maxillary length (28)	271	265	261	270	271	265	268	290	270	276	267	276	286	265	285	290	281	282	290
Orbit diameter (29)	48	48	51	52	51	55	48	50	53	51	50	50	50	51	51	53	52	52	52
Depth of bill (33)	16.7	14.9	17.6	15.5	15.5	15.1	16.7	16.0	15.0	15.4	—	15.8	15.2	16.7	16.3	16.4	17.9	17.4	15.2
Width of bill (34)	23.3	24.9	26.2	22.2	22.2	24.5	22.8	22.2	23.6	24.4	—	25.8	23.3	26.7	23.8	25.2	26.4	26.5	23.8
Height D_1 (39)	367	340	325	356	275	310	380	347	320	335	355	340	322	363	368	—	360	359	—
Length 25th D_1 spine (40)	85	—	66	89	79	85	—	87	—	101	82	90	—	83	93	98	107	92	72
Height D_2 (41)	73	66	70	68	67	58	76	69	—	69	67	73	70	73	75	67	75	75	67
Height A_1 (42)	236	228	234	248	232	232	250	245	230	245	240	242	235	252	260	232	261	252	233
Height A_2 (43)	53	51	—	—	48	47	58	—	51	53	54	52	56	52	—	52	58	61	51
Length P_1 (44)	400	406	375	382	374	380	442	427	408	405	415	410	390	408	451	400	416	395	385
Length P_2 (45)	346	330	320	—	314	—	342	—	314	286	—	290	286	315	—	—	290	—	248
Length last D_2 ray	115	114	90	102	99	87	105	105	95	99	103	—	106	107	112	109	100	98	94
Length last A_2 ray	107	110	90	82	101	79	102	96	97	93	99	98	105	99	86	92	105	97	93
Orig. D_1 to orig. D_2	935	990	955	973	990	990	982	1,000	1,005	1,030	1,005	1,000	1,025	1,010	972	1,025	1,035	1,070	1,020
Anus to orig. A_1	74	70	71	72	75	75	87	74	79	70	71	80	80	80	74	73	90	65	70
Weight (lb)	53.9	59.4	55	55	56.1	59.4	55.5	69.3	61.6	63.8	58.3	61.6	57.2	66.0	63.8	68.6	70.4	63.8	55
Weight (kg)	24.5	27	25	25	25.5	27	25.3	31.5	28	29	26.5	28	26	30	29	31	32	29	25

Appendix Table 1.—Morphometric data for 56 specimens of *Tetrapturus albidus* from the eastern North Atlantic—(*continued*).

Specimen Number	28	18	35	14	23	32	49	19	47	15	24	3	41	21	13	7	8	17	40
Body length (1)	1,770	1,770	1,780	1,783	1,790	1,796	1,800	1,810	1,810	1,815	1,815	1,820	1,825	1,830	1,835	1,845	1,845	1,850	1,850
First predorsal length (3)	410	419	406	412	410	408	414	407	432	396	446	445	435	425	430	418	432	426	430
Second predorsal length (4)	1,450	1,440	1,470	1,462	1,440	1,448	1,450	1,500	1,480	1,480	1,460	1,482	1,465	1,500	1,500	1,500	1,505	1,510	1,505
Prepectoral length (5)	475	468	476	478	460	465	480	474	471	472	490	486	490	465	470	478	495	476	467
Prepelvic length (6)	503	500	495	510	492	486	498	487	495	496	520	508	530	490	495	505	533	505	505
First preanal length (7)	1,080	1,075	1,095	1,072	1,070	1,062	1,070	1,100	1,095	1,092	1,075	1,078	—	1,090	1,110	1,097	1,100	1,100	1,105
Second preanal length (8)	1,430	1,400	1,430	1,432	1,415	1,430	1,420	1,450	1,440	1,440	1,445	1,457	1,435	1,455	1,445	1,460	1,462	1,472	1,470
Orig. D_1 to orig. P_1 (9)	225	240	222	236	220	230	238	222	242	232	228	224	250	237	250	224	243	240	230
Orig. D_1 to orig. P_2 (10)	284	306	295	290	294	296	310	274	305	295	298	300	315	305	310	285	315	315	308
Orig. D_2 to orig. A_2 (11)	154	161	168	165	162	173	166	170	165	170	160	168	176	172	172	165	170	170	175
Tip mandible to anus	995	992	1,010	993	985	980	1,000	1,010	1,020	997	1,005	1,008	1,085	1,015	1,030	1,015	1,010	1,025	1,015
Orig. P_2 to nape (13)	290	305	290	299	291	292	295	271	305	290	290	289	314	297	304	297	310	312	290
Greatest body depth (14)	270	310	290	290	280	300	314	278	310	290	290	305	315	304	306	275	310	312	315
Depth at orig. D_1 (15)	270	295	280	282	290	280	300	265	304	290	288	289	305	295	300	270	305	312	300
Depth at orig. A_1 (16)	206	245	238	221	237	246	234	230	235	242	226	252	250	240	238	245	250	245	242
Least depth c.p. (17)	65	70	66	75	67	70	68	69	61	72	71	73	73	72	68	63	73	75	67
Width at P_1 base (18)	130	140	125	130	140	137	145	154	125	142	137	150	138	132	140	152	145	130	152
Width at A_1 orig. (19)	122	140	140	153	124	147	155	152	147	150	130	165	155	154	135	143	150	140	164
Width at A_2 orig. (20)	90	117	100	120	105	120	118	110	110	115	105	117	125	108	102	112	116	106	125
Width c.p. (in front of keels)	50	54	54	56	50	59	56	49	59	54	51	61	60	69	53	49	58	52	56
Length upper keel (22)	62	69	66	78	68	65	65	64	69	66	63	57	73	65	69	53	66	66	65
Length lower keel (23)	51	64	58	64	65	55	61	59	64	59	61	54	63	59	59	56	56	59	64
Head length (24)	465	462	460	465	461	460	470	460	460	455	486	475	475	455	465	458	480	460	477
Snout length (25)	225	219	220	228	220	215	226	220	220	215	246	235	230	212	215	216	235	220	232
Bill length (26)	530	540	510	515	510	505	555	476	545	—	577	465	—	—	500	504	545	490	468
Maxillary length (28)	295	295	294	300	294	290	304	290	290	292	314	310	305	290	294	290	315	300	308
Orbit diameter (29)	51	54	55	50	52	54	53	55	54	54	52	54	56	54	56	54	55	53	55
Depth of bill (33)	18.2	18.6	15.2	16.2	17.6	17.6	16.3	19.0	17.7	18.6	19	14.8	17.2	18.6	19.6	16.5	16.5	15.2	17.4
Width of bill (34)	25.1	24.5	21.7	22.8	26.0	26.9	26.5	27.0	25.0	29.1	25	26.5	26.0	28.4	30.5	22.8	26.2	26.6	27.0
Height D_1 (39)	355	368	347	347	372	365	360	369	340	320	388	380	370	340	—	370	382	355	—
Length 25th D_1 spine (40)	84	82	95	96	83	84	84	86	86	71	94	99	73	88	—	86	100	79	95
Height D_2 (41)	84	75	59	69	77	67	80	68	69	—	56	75	75	74	—	68	77	73	73
Height A_1 (42)	242	242	242	250	274	245	258	250	245	—	267	265	252	245	245	270	270	256	240
Height A_2 (43)	60	67	59	—	—	57	59	56	57	-	71	56	52	69	—	—	58	56	65
Length P_1 (44)	431	460	396	418	434	405	425	417	420	415	430	456	415	425	418	400	420	416	412
Length P_2 (45)	325	—	300	—	—	315	—	—	—	279	342	340	327	298	302	300	370	-	300
Length last D_2 ray	106	105	96	99	107	104	109	97	108	108	100	105	124	90	109	96	108	107	112
Length last A_2 ray	94	—	89	96	93	88	102	93	102	105	105	114	111	94	92	93	104	97	111
Orig. D_1 to orig. D_2	1,062	1,060	1,072	1,060	1,060	1,068	1,050	1,110	1,080	1,085	1,060	1,080	1,055	1,100	1,100	1,108	1,090	1,115	1,095
Anus to orig. A_1	78	71	82	90	86	83	76	60	82	85	82	82	80	85	74	79	85	78	81
Weight (lb)	55	74.8	68.2	70.4	59.4	79	78.1	70.7	86.9	79.2	68.2	79.2	92.4	—	74.8	77	83.6	77	88
Weight (kg)	25	34	31	32	27	36	35.5	32	39.5	36	31	36	42	—	34	35	38	35	40

Apprendix Table 1.—Morphometric data for 56 specimens of *Tetrapturus albidus* from the eastern North Atlantic—(*continued*).

Specimen Number	56	16	9	36	27	48	43	45	6	55	2	30	54	37	12	5	26	44
Body length (1)	1,860	1,860	1,875	1,882	1,894	1,895	1,900	1,905	1,920	1,928	1,932	1,932	1,942	1,965	1,970	1,985	2,020	2,030
First predorsal length (3)	438	445	465	436	425	416	444	458	440	476	432	445	435	444	469	485	462	480
Second predorsal length (4)	1,500	1,500	1,560	1,520	1,525	1,530	1,560	1,545	1,550	1,560	1,575	1,565	1,580	1,595	1,585	1,620	1,655	1,665
Prepectoral length (5)	486	491	495	482	500	472	495	514	510	521	505	503	504	510	492	485	540	512
Prepelvic length (6)	503	520	525	515	535	497	525	546	543	542	532	535	535	532	534	537	555	588
First preanal length (7)	1,120	1,160	1,127	1,118	1,137	1,140	1,140	—	1,152	1,130	1,158	1,162	1,165	1,165	1,220	1,200	1,200	1,235
Second preanal length (8)	1,470	1,482	1,520	1,495	1,505	1,490	1,525	1,195	1,500	1,530	1,540	1,530	1,552	1,570	1,565	1,575	1,620	1,610
Orig. D_1 to orig. P_1 (9)	255	231	254	250	257	266	250	248	255	250	256	244	263	254	246	270	275	288
Orig. D_1 to orig. P_2 (10)	322	295	315	318	328	333	320	326	325	318	326	308	340	326	325	337	330	383
Orig. D_2 to orig. A_2 (11)	186	168	175	176	186	192	182	155	184	178	180	175	182	191	176	167	184	195
Tip mandible to anus	1,035	1,050	1,050	1,015	1,046	1,060	1,060	1,100	1,060	1,060	1,065	1,080	1,060	1,060	1,105	1,115	1,111	1,145
Orig. P_2 to nape (13)	300	300	310	316	322	333	315	322	310	320	315	312	335	320	315	330	330	370
Greatest body depth (14)	340	290	315	321	326	340	330	331	325	320	320	312	340	327	325	340	326	385
Depth at orig. D_1 (15)	306	275	305	310	326	334	308	315	318	318	320	300	329	317	310	328	315	370
Depth at orig. A_1 (16)	265	242	250	262	267	266	280	265	275	240	264	251	266	260	254	265	268	315
Least depth c.p. (17)	78	70	66	77	77	78	76	74	75	72	71	73	77	77	77	76	75	81
Width at P_1 base (18)	142	148	156	137	150	146	156	147	145	145	146	145	140	150	136	158	152	162
Width at A_1 orig. (19)	157	140	148	150	170	160	178	170	126	148	160	150	156	165	145	157	154	182
Width at A_2 orig. (20)	120	110	128	120	126	125	135	128	150	115	123	123	120	118	118	120	115	137
Width c.p. (in front of keels)	59	53	60	68	68	65	61	64	61	53	64	59	67	63	55	69	61	69
Length upper keel (22)	72	62	64	72	69	80	65	73	78	66	66	65	78	73	72	77	72	79
Length lower keel (23)	62	59	56	60	67	67	65	63	66	66	57	61	63	62	65	73	62	73
Head length (24)	485	475	486	480	480	454	486	505	485	498	486	486	495	486	493	515	518	523
Snout length (25)	238	230	233	230	230	192	235	248	237	235	232	237	230	232	228	248	255	252
Bill length (26)	542	—	528	—	555	510	—	572	485	566	520	515	495	535	520	540	578	505
Maxillary length (28)	316	308	315	311	308	275	312	330	315	320	302	318	310	311	316	340	338	340
Orbit diameter (29)	54	53	58	57	56	56	56	56	56	57	57	57	58	55	60	60	57	59
Depth of bill (33)	18.3	18.0	18.0	16.1	19.2	21.5	22.9	17.7	16.0	18.0	18.3	15.9	18.4	20.1	18.8	19.0	19.4	18.5
Width of bill (34)	28.8	24.6	28.4	27.3	30.8	37.2	29.5	26.9	26.8	26.1	31.4	25.7	31.6	29.8	30.1	29.8	27.0	31.1
Height D_1 (39)	—	380	355	362	365	358	360	380	415	382	375	372	385	382	375	415	406	360
Length 25th D_1 spine (40)	93	80	92	—	90	96	79	74	92	85	95	88	95	87	91	89	92	124
Height D_2 (41)	68	78	65	68	77	70	69	89	82	—	76	71	76	76	68	74	—	76
Height A_1 (42)	254	254	260	243	255	245	245	250	270	274	236	251	270	270	250	248	274	254
Height A_2 (43)	53	—	56	57	59	56	62	—	64	69	60	62	59	56	77	—	62	75
Length P_1 (44)	422	444	420	410	426	397	395	428	450	430	455	375	423	460	445	435	446	428
Length P_2 (45)	270	355	—	—	—	—	—	352	318	—	—	—	300	—	—	—	285	—
Length last D_2 ray	103	114	79	114	103	111	108	96	113	120	118	98	103	105	106	112	102	—
Length last A_2 ray	106	107	97	101	103	101	102	83	114	110	109	94	101	103	101	103	104	—
Orig. D_1 to orig. D_2	1,090	1,082	1,135	1,118	1,110	1,140	1,160	1,095	1,125	1,130	1,146	1,140	1,185	1,160	1,165	1,175	1,215	1,210
Anus to orig. A_1	84	86	79	91	89	85	86	91	95	84	82	82	96	94	98	90	83	90
Weight (lb)	92.4	77	90.2	88	96.8	101.7	105.6	101.2	92.4	81.4	92.4	88	99	99	94.6	99	96.8	139.7
Weight (kg)	42	35	41	40	44	46.3	48	46	42	37	42	40	45	45	43	45	44	63.5

Appendix Table 2.—Morphometric data for 56 specimens of *Tetrapturus albidus* from the eastern North Atlantic expressed in percentage of body length. Measurements are as defined by Rivas (1956) unless otherwise indicated. Numbers in parentheses refer to the numbered definitions of Rivas; see text for explanation of abbreviations.

Specimen Numbers	52	38	34	33	57	11	39	42	50	51	46	20	22	29	1	4	25	31	10
Body length (1) (mm)	1,600	1,610	1,620	1,628	1,640	1,640	1,662	1,670	1,675	1,685	1,700	1,705	1,705	1,710	1,715	1,730	1,734	1,745	1,745
First predorsal length (3)	24	23	23	23	22	24	23	24	23	24	22	23	24	22	23	24	24	23	23
Second predorsal length (4)	81	83	80	82	82	82	80	—	82	—	77	82	82	80	79	82	82	83	81
Prepectoral length (5)	25	26	26	26	25	27	26	27	26	26	26	26	27	25	26	26	27	25	27
Prepelvic length (6)	28	28	28	28	27	29	27	28	28	28	26	29	28	28	28	28	28	27	29
First preanal length (7)	60	60	60	61	59	60	59	61	60	59	57	61	60	60	59	60	60	58	60
Second preanal length (8)	79	80	80	80	79	80	78	80	79	79	75	79	80	79	79	79	80	79	80
Orig. D_1 to orig. P_1 (9)	12	13	13	12	13	13	13	14	12	13	12	13	13	12	12	12	13	12	12
Orig. D_1 to orig. P_2 (10)	16	17	16	16	17	17	17	18	17	17	16	17	16	17	16	16	17	16	16
Orig. D_2 to orig. A_2 (11)	9.4	9.7	9.0	8.9	9.1	8.9	8.7	10	9.3	9.3	8.8	9.1	9.0	9.6	9.0	9.5	9.5	9.0	8.1
Tip mandible to anus	56	55	56	57	54	56	54	56	56	56	53	56	55	56	54	56	55	55	56
Orig. P_2 to nape (13)	16	16	17	18	16	18	16	17	17	17	16	17	16	17	15	16	17	16	16
Greatest body depth (14)	16	16	17	17	17	17	16	18	17	16	16	16	16	17	16	16	16	16	15
Depth at orig. D_1 (15)	15	16	16	16	16	17	16	17	17	16	16	16	15	16	16	16	16	15	15
Depth at orig. A_1 (16)	13	14	13	13	13	13	13	15	13	13	12	13	13	13	13	14	14	13	12
Least depth c.p. (17)	4.1	3.9	4.0	3.9	3.8	4.0	3.7	4.2	3.9	3.9	3.5	4.2	3.9	3.8	4.0	4.3	4.1	3.7	3.7
Width at P_1 base (18)	7.8	7.6	8.3	7.6	7.3	7.3	7.7	8.4	7.5	7.7	7.0	7.9	7.0	7.6	7.6	8.3	8.0	7.4	7.0
Width at A_1 orig. (19)	7.8	8.1	8.0	7.5	7.9	8.0	7.6	9.3	7.5	8.5	7.3	7.5	7.3	8.5	8.0	8.1	8.2	8.3	7.5
Width at A_2 orig. (20)	6.1	6.8	—	6.1	6.2	6.3	6.6	7.2	6.1	6.5	5.8	5.9	6.3	6.7	6.8	7.4	6.5	6.0	5.4
Width c.p. (in front of keels)	3.1	3.3	3.7	3.1	3.0	2.7	3.0	3.4	3.3	3.0	2.9	3.0	2.9	3.3	3.7	3.6	3.2	3.0	2.5
Length upper keel (22)	3.6	3.3	3.8	4.0	3.5	3.6	3.4	3.5	3.2	3.4	3.8	4.0	3.9	3.9	3.4	3.6	3.5	3.3	3.9
Length lower keel (23)	3.4	2.7	3.3	3.7	3.3	3.4	3.5	3.2	3.1	3.0	3.0	3.2	3.2	3.3	3.3	3.3	3.3	3.2	3.3
Head length (24)	26	26	26	26	25	26	25	26	25	26	24	26	26	25	26	26	26	25	26
Snout length (25)	13	12	12	13	13	12	12	13	12	12	11	12	13	11	13	13	12	12	12
Bill length (26)	—	30	29	29	25	—	30	—	28	—	—	28	30	30	30	28	30	28	27
Maxillary length (28)	17	16	16	16	17	16	16	17	16	16	15	16	17	16	17	17	16	16	17
Orbit diameter (29)	3.0	3.0	3.1	3.2	3.1	3.4	2.9	3.0	3.2	3.0	2.8	2.9	2.9	3.0	3.0	3.1	3.0	3.0	3.0
Depth of bill (33)	1.04	0.93	1.09	0.95	0.94	0.92	1.00	0.96	0.90	0.91	—	0.93	0.89	0.98	0.95	0.94	1.03	1.00	0.87
Width of bill (34)	1.5	1.5	1.6	1.4	1.4	1.5	1.4	1.3	1.4	1.4	—	1.5	1.4	1.6	1.4	1.5	2.0	2.0	0.14
Height D_1 (39)	23	21	20	22	17	19	23	20	19	20	20	20	19	21	22	—	20	20	—
Length 25th D_1 spine (40)	5.3	—	4.1	5.5	4.8	5.2	—	5.2	—	6.0	4.6	5.3	—	4.9	5.4	5.7	6.2	5.3	4.1
Height D_2 (41)	4.6	4.1	4.3	4.2	4.0	3.5	4.6	4.1	—	4.1	3.7	4.3	4.1	4.3	4.4	3.9	4.3	4.3	3.8
Height A_1 (42)	15	14	14	15	14	14	15	15	14	14	13	14	14	15	15	13	15	14	13
Height A_2 (43)	3.3	3.2	—	—	2.9	2.9	3.5	—	3.0	3.1	3.0	3.0	3.3	3.0	—	3.0	3.3	3.5	2.9
Length P_1 (44)	25	25	23	23	23	23	27	26	24	24	23	24	23	24	26	23	24	23	22
Length P_2 (45)	22	20	20	—	19	—	20	—	19	17	—	17	17	18	—	—	17	—	14
Length last D_2 ray	7.2	7.1	5.6	6.3	6.0	5.3	6.3	6.3	5.7	5.9	5.7	—	6.2	6.3	6.5	6.3	5.8	5.6	5.4
Length last A_2 ray	6.7	6.8	5.6	5.0	6.2	4.8	6.1	5.7	5.8	5.5	5.5	5.7	6.2	5.8	5.0	5.3	6.1	5.6	5.3
Orig. D_1 to orig. D_2	58	62	59	60	60	60	59	60	60	61	56	59	60	59	57	59	60	61	58
Anus to orig. A_1	4.6	4.3	4.4	4.4	4.5	4.6	5.2	4.4	4.7	4.2	4.0	4.7	4.7	4.7	4.3	4.2	5.2	3.7	4.0
Weight (lb)	53.9	59.4	55	55	56.1	59.4	55	69.3	61.6	63.8	58.3	61.6	57.2	66.0	63.8	68.6	70.4	63.8	55

Appendix Table 2.—Morphometric data for 56 specimens of *Tetrapturus albidus* from the eastern North Atlantic expressed in percentage of body length—(*continued*).

Specimen Numbers	28	18	35	14	23	32	49	19	47	15	24	3	41	21	13	7	8	17	40
Body length (1) (mm)	1,770	1,770	1,780	1,783	1,790	1,796	1,800	1,810	1,810	1,815	1,815	1,820	1,825	1,830	1,835	1,845	1,845	1,850	1,850
First predorsal length (3)	23	24	23	23	23	23	23	22	24	22	25	24	24	23	23	23	23	23	23
Second predorsal length (4)	82	81	83	82	80	80	80	83	—	82	80	81	80	82	82	81	82	82	81
Prepectoral length (5)	27	26	27	27	26	26	27	26	26	26	27	27	27	25	26	26	27	26	25
Prepelvic length (6)	28	28	28	29	28	27	28	27	27	27	29	28	29	27	27	27	29	27	27
First preanal length (7)	61	60	62	60	60	59	59	60	60	60	59	59	—	60	60	60	60	60	60
Second preanal length (8)	80	79	80	80	79	80	79	80	80	79	80	80	79	80	79	79	79	80	80
Orig. D_1 to orig. P_1 (9)	13	14	12	13	12	13	13	12	13	13	13	12	14	13	14	12	13	13	12
Orig. D_1 to orig. P_2 (10)	16	17	17	16	16	16	17	15	17	16	16	16	17	17	17	15	17	17	17
Orig. D_2 to orig. A_2 (11)	8.7	9.1	9.4	9.3	9.1	9.6	9.2	9.4	9.1	9.4	8.8	9.2	9.6	9.4	9.4	8.9	9.2	9.2	9.5
Tip mandible to anus	56	56	57	56	55	55	56	56	56	55	55	55	59	56	56	55	55	55	55
Orig. P_2 to nape (13)	16	17	16	17	16	16	16	15	17	16	16	16	17	16	17	16	17	17	16
Greatest body depth (14)	15	18	16	16	16	17	17	15	17	16	16	17	17	16	17	15	17	17	17
Depth at orig. D_1 (15)	15	17	16	16	16	16	17	15	17	16	16	16	17	16	16	15	16	17	16
Depth at orig. A_1 (16)	12	14	13	12	13	14	13	13	13	13	12	14	14	13	13	13	14	13	13
Least depth c.p. (17)	3.7	4.0	3.7	4.2	3.7	3.9	3.8	3.8	3.4	4.0	3.9	4.0	4.0	3.9	3.7	3.4	4.0	4.1	3.6
Width at P_1 base (18)	7.3	7.9	7.0	7.3	7.8	7.6	8.1	8.5	6.9	7.8	7.5	8.2	7.6	7.2	7.6	8.2	7.9	7.0	8.2
Width at A_1 orig. (19)	6.9	7.9	7.9	8.6	6.9	8.2	8.6	8.4	8.1	8.3	7.2	9.1	8.5	8.4	7.4	7.8	8.1	7.6	8.9
Width at A_2 orig. (20)	5.1	6.6	5.6	6.7	5.9	6.7	6.6	6.1	6.1	6.3	5.8	6.4	6.8	5.9	5.6	6.1	6.3	5.7	6.8
Width c.p. (in front of keels)	2.8	3.1	3.0	3.1	2.8	3.3	3.1	2.7	3.3	3.0	2.8	3.4	3.3	3.8	2.9	2.7	3.1	2.8	3.0
Length upper keel (22)	3.5	3.9	3.7	4.4	3.8	3.6	3.6	3.5	3.8	3.6	3.5	3.1	4.0	3.6	3.8	2.9	3.6	3.6	3.5
Length lower keel (23)	2.9	3.6	3.3	3.6	3.6	3.1	3.4	3.3	3.5	3.3	3.4	3.0	3.5	3.2	3.2	3.0	3.0	3.2	3.5
Head length (24)	26	26	26	26	26	26	26	25	25	25	27	26	26	25	25	25	26	25	26
Snout length (25)	13	12	12	13	12	12	13	12	12	12	14	13	13	12	12	12	13	12	12
Bill length (26)	30	30	29	29	28	28	30	26	30	—	32	26	—	—	27	27	30	26	25
Maxillary length (28)	17	17	16	17	16	16	17	16	16	16	17	17	17	16	16	16	17	16	17
Orbit diameter (29)	2.9	3.1	3.1	2.8	2.9	3.0	2.9	3.0	3.0	3.0	2.9	3.0	3.1	3.0	3.1	2.9	3.0	2.9	3.0
Depth of bill (33)	1.03	1.05	.85	.91	.98	.98	.91	1.05	.98	1.02	1.05	.81	.94	1.02	1.07	.89	.89	.82	.94
Width of bill (34)	1.4	1.4	1.2	1.3	1.5	1.5	1.5	1.5	1.4	1.6	1.4	1.5	1.4	1.6	1.7	1.2	1.4	1.4	1.5
Height D_1 (39)	20	20	20	20	20	20	20	20	19	18	21	20	20	19	—	20	20	19	—
Length 25th D_1 spine (40)	4.7	4.6	5.3	5.4	4.6	4.7	4.7	4.8	4.8	3.9	5.2	5.4	4.0	4.8	—	4.7	5.4	4.3	5.1
Height D_2 (41)	4.7	4.2	3.3	3.9	4.3	3.7	4.4	3.8	3.8	—	3.1	4.1	4.1	4.0	—	3.7	4.2	3.9	3.9
Height A_1 (42)	14	14	14	14	15	14	14	14	14	—	15	15	14	13	13	15	15	14	13
Height A_2 (43)	3.4	3.8	3.3	—	—	3.2	3.3	3.1	3.1	—	3.9	3.1	2.8	3.8	—	—	3.1	3.0	3.5
Length P_1 (44)	24	26	22	23	24	23	24	23	23	23	24	25	23	23	23	22	23	22	22
Length P_2 (45)	18	—	17	—	—	18	—	—	—	15	19	19	18	16	16	16	20	—	16
Length last D_2 ray	6.0	5.9	5.4	5.6	6.0	5.8	6.1	5.4	6.0	6.0	5.5	5.8	6.8	4.9	5.9	5.2	5.9	5.8	6.1
Length last A_2 ray	5.3	—	5.0	5.4	5.2	4.9	5.7	5.1	5.6	5.8	5.8	6.3	6.1	5.1	5.0	5.0	5.6	5.2	6.0
Orig. D_1 to orig. D_2	60	60	60	60	59	60	58	61	60	60	58	59	58	60	60	60	59	60	59
Anus to orig. A_1	4.4	4.0	4.6	5.0	4.8	4.6	4.2	3.3	4.5	4.7	4.5	4.5	4.4	4.6	4.0	4.3	4.6	4.2	4.4
Weight (lb)	55	74.8	68.2	70.4	59.4	79	78.1	70.7	86.9	79.2	68.2	79.2	92.4	—	74.8	77	83.6	77	88

Appendix Table 2.--Morphometric data for 56 specimens of *Tetrapturus albidus* from the eastern North Atlantic expressed in percentage of body length--(*continued*).

Specimen Numbers	56	16	9	36	27	48	43	45	6	55	2	30	54	37	12	5	26	44
Body length (1) (mm)	1,860	1,860	1,875	1,882	1,894	1,895	1,900	1,905	1,920	1,928	1,932	1,932	1,942	1,965	1,970	1,985	2,020	2,030
First predorsal length (3)	24	24	25	23	22	22	23	24	23	25	22	23	22	23	24	24	23	24
Second predorsal length (4)	80	80	83	80	80	—	82	81	80	80	82	81	81	81	80	82	82	82
Prepectoral length (5)	26	26	26	26	26	25	26	27	27	27	26	26	26	26	25	24	27	25
Prepelvic length (6)	27	28	28	27	28	26	28	29	28	28	28	28	28	27	27	27	28	29
First preanal length (7)	60	62	60	59	60	60	60	—	60	59	60	60	60	59	62	60	59	60
Second preanal length (8)	79	80	81	79	80	79	80	63	78	79	80	79	80	80	79	79	80	79
Orig. D₁ to orig. P₁ (9)	14	12	14	13	14	14	13	13	13	13	13	13	14	13	12	14	14	14
Orig. D₁ to orig. P₂ (10)	17	16	17	17	17	18	17	17	17	16	17	16	18	17	16	17	16	19
Orig. D₂ to orig. A₂ (11)	10	9.0	9.3	9.4	9.8	10	9.6	8.1	9.6	9.2	9.3	9.1	9.4	9.7	8.9	8.4	9.1	9.6
Tip mandible to anus	56	56	56	54	55	56	56	58	55	55	55	60	55	54	56	56	55	56
Orig. P₂ to nape (13)	16	16	16	17	17	18	17	17	16	17	16	16	17	16	16	17	16	18
Greatest body depth (14)	18	16	17	17	17	18	17	17	17	17	17	16	18	17	16	17	16	19
Depth at orig. D₁ (15)	16	15	16	16	17	18	16	16	17	16	17	16	17	16	16	16	16	18
Depth at orig. A₁ (16)	14	13	13	14	14	14	15	14	14	12	14	13	14	13	13	13	13	16
Least depth c.p. (17)	4.1	3.0	3.5	4.1	4.1	4.1	4.0	3.9	3.9	3.7	3.7	3.8	4.0	3.9	3.9	3.8	3.7	4.0
Width at P₁ base (18)	7.6	8.0	8.3	7.3	7.9	7.7	8.2	7.7	7.6	7.5	7.6	7.5	7.2	7.6	6.9	8.0	7.5	8.0
Width at A₁ orig. (19)	8.4	7.5	7.9	8.0	9.0	8.4	9.4	8.9	6.6	7.7	8.3	7.8	8.0	8.4	7.4	7.9	7.6	9.0
Width at A₂ orig. (20)	6.4	5.9	6.8	6.4	6.7	6.6	7.1	6.7	7.8	5.9	6.4	6.4	6.2	6.0	6.0	6.0	5.7	6.7
Width c.p. (in front of keels)	3.1	2.8	3.2	3.6	3.6	3.4	3.2	3.4	3.2	2.7	3.3	3.1	3.4	3.2	2.8	3.5	3.0	3.4
Length upper keel (22)	3.8	3.3	3.4	3.8	3.6	4.2	3.4	3.8	4.1	3.4	3.4	3.4	4.0	3.7	3.7	3.9	3.6	3.9
Length lower keel (23)	3.3	3.2	3.0	3.2	3.5	3.5	3.4	3.3	3.4	3.4	3.0	3.2	3.2	3.2	3.3	3.7	3.1	3.6
Head length (24)	26	26	26	26	25	24	26	26	25	25	25	25	26	25	25	26	26	26
Snout length (25)	13	12	12	12	12	10	12	13	12	12	12	12	12	12	12	12	13	12
Bill length (26)	29	—	28	—	29	27	—	30	25	29	27	27	26	27	26	27	29	25
Maxillary length (28)	17	17	17	16	16	14	16	17	16	17	16	16	16	16	16	17	17	17
Orbit diameter (29)	2.9	2.8	3.1	3.0	3.0	3.0	2.9	2.9	2.9	2.9	3.0	3.0	3.0	2.8	3.0	3.0	2.8	2.9
Depth of bill (33)	.98	.97	.96	.86	1.01	1.13	1.21	.93	.83	.93	.95	.82	.95	1.02	.95	.96	.96	.91
Width of bill (34)	1.5	1.3	1.5	1.5	1.6	2.0	1.6	1.4	1.4	1.3	1.6	1.3	1.6	1.5	1.5	1.5	1.3	1.5
Height D₁ (39)	—	20	19	19	19	19	19	20	22	20	19	19	20	19	19	20	20	18
Length 25th D₁ spine (40)	5.0	4.3	4.9	—	4.8	5.1	4.2	3.9	4.8	4.4	4.9	4.6	4.9	4.4	4.6	4.5	4.6	6.1
Height D₂ (41)	3.6	4.2	3.5	3.6	4.1	3.7	3.6	4.7	4.3	—	3.9	3.7	3.9	3.9	3.5	3.7	—	3.7
Height A₁ (42)	14	14	14	13	14	13	13	13	14	14	12	13	14	14	13	12	14	12
Height A₂ (43)	2.8	—	3.0	3.0	3.1	3.0	3.3	—	3.3	3.5	3.1	3.2	3.0	2.8	3.9	—	3.1	3.7
Length P₁ (44)	22	24	22	22	22	20	20	22	23	22	24	19	22	23	23	22	23	21
Length P₂ (45)	14	19	—	—	—	—	—	18	17	—	—	—	15	—	—	—	14	—
Length last D₂ ray	5.5	6.1	4.2	6.1	5.4	5.9	5.7	5.0	5.9	6.2	6.1	5.1	5.3	5.3	5.4	5.6	5.0	—
Length last A₂ ray	5.7	5.9	5.2	5.4	5.4	5.3	5.4	4.4	5.9	5.7	5.6	4.9	5.2	5.2	5.1	5.2	5.1	—
Orig. D₁ to orig. D₂	59	58	60	59	59	60	61	58	59	59	59	59	61	59	59	59	60	60
Anus to orig. A₁	4.5	4.6	4.2	4.8	4.7	4.5	4.5	4.8	4.9	4.3	4.2	4.2	4.9	4.8	5.0	4.5	4.1	4.4
Weight (lb)	92.4	77	90.2	88	96.8	101.7	105.6	101.2	92	81.4	92.4	88	99	99	94.6	99	96.8	139.7

The Cape of Good Hope: A Hidden Barrier to Billfishes

M. J. PENRITH[1] and D. L. CRAM[2]

ABSTRACT

Since 1838 there have been isolated reports of billfishes from the southern tip of Africa, but only during the years 1961-64, when a number of Cape Town based boats fished commercially for tuna using longlines, were billfishes found to occur in considerable numbers.

The waters to the west and south of the Cape of Good Hope were found to be unique in their billfish fauna, no less than six species being represented, comprising *Xiphias*, *Makaira* (2 species) and *Tetrapturus* (3 species). Only two wide-ranging species have not been found. *Istiophorus* is commonly listed from the area on the basis of *Histiophorus granulifer*, but a reexamination of de Castelnau's type shows it to be a *Makaira*, while *T. angustirostris* could occur as it is known from off Durban.

The billfishes are probably attracted to this limited geographic area by the rich feeding grounds which are the result of the upwelling of nutrient-rich water along the Cape's west coast. It is difficult, however, to suggest reasons why there is an apparent barrier to movement between the Atlantic and Indo-Pacific Oceans for certain species. Hydrographic conditions in the area are discussed, but there are no obvious physical barriers preventing black and striped marlins from entering the Atlantic nor white marlin and longbill spearfish from moving into the Indo-Pacific.

The African landmass is unique, since of all the major landmasses it alone does not project sufficiently polewards to form a complete barrier to the east-west movement of all the larger mobile warm-water oceanic fish. All the same, it has traditionally been considered a barrier to the movement of billfishes between the Atlantic and Indo-Pacific Oceans. This concept of a barrier has to a large extent been strengthened by the very marked differences in the inshore marine fauna of the two sides of the southern African coast (Ekman, 1953).

The term Cape of Good Hope can be used for any of three areas. In the strict cartographic sense it is a minor land projection to the west of Cape Point on the southern end of the Cape Peninsula. Historically it embraced the area from about Cape Columbine to the region of Cape Agulhas; this was the area where the early East-Indiamen made their first landfall when rounding the tip of Africa. Finally, the 19th century biologists used the Cape of Good Hope in a very wide sense to include the whole southern tip of Africa and its adjacent seas. In this paper the Cape of Good Hope is used in the same sense as the early navigators used it, that is to include the land and adjacent seas to the south and west of the Cape Peninsula (Fig. 1). Following the conventional divisions of the oceans this area is within the Atlantic Ocean, but is in reality a very confused area for the oceanographer. Water from at least four sources can occur as surface water in the area, being either surface water of South Atlantic or Indian Ocean (Agulhas Current) origin, mixed Agulhas Bank water, or upwelled water of probably South Atlantic Central water origin (Shannon, 1966; Visser, 1969). The exact position of these water masses in relation to each other is dependent on a number of factors, but the direction and strength of the winds, both local and as far removed as the monsoons of the northern Indian Ocean, are the dominant factors. The hydrography will be described more fully below, but in general there is an east-west oscillation of Atlantic and Indian (Agulhas Current) surface waters with southerly and westerly movements of upwelled water.

The first record of a billfish from the Cape of Good Hope was the description by Gray (1838) of *Tetrapturus herschelii* (= *Makaira nigricans*). Thereafter there were very few records of billfishes indeed (Table 1), with the exception of a number of catches of *Xiphias gladius* since 1956 by deep-water trawlers.

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Table 1.—Billfishes recorded from the Cape of Good Hope.

Date	Locality	[1]Method	[2]Size
	Xiphias gladius		
15.2.56	Dassen Isl.	B	1,060 mm
20.7.56	40 miles W. Slangkop	B	2,620 mm
19.8.56	40 miles W. Slangkop	B	32 kg.
25.3.58	False Bay	X	558 mm
7.3.58	W. Slangkop	B	875 mm
8.3.58	15 miles S.W. Cape Point	T	875 mm
14.4.59	30 miles W. Slangkop	B	86 kg
8.10.60	60 miles W. Slangkop	L	170 kg
12.1.61	20 miles W. Slangkop	B	106 kg
3.4.61	W. Danger Point	B	± 3 kg
1.11.61	S.W. Slangkop	L	± 190 kg
22.2.62	W. Slangkop	[3]L	± 4 kg
22.2.62	30 miles W. Cape Point	L	± 55 kg
1.3.62	W. Peninsula	L	± 60 kg
30.3.62	W. Peninsula	L	± 1 kg
31.3.62	W. Peninsula	L	± 1 kg
	Makaira indica		
16.1.61	W. Peninsula	L	3,527 mm
27.1.61	W. Peninsula	L	3,334 mm
21.2.61	30 miles W. Slangkop	L	3,559 mm
2.3.61	35 miles W. Slangkop	L	3,558 mm
3.3.61	W. Slangkop	L	2,850 mm
13.3.61	W. Slangkop	L	± 340 kg
13.3.61	W. Slangkop	L	± 370 kg
14.3.61	W. Cape Point	L	3,180 mm
15.3.61	W. Danger Point	L	3,000 mm
20.3.61	W. Cape Point	L	± 370 kg
9.1.62	W. Dassen Isl.	L	2,959 mm
11.1.62	W. Peninsula	L	3,487 mm
15.1.62	W. Cape Town	L	± 370 kg
28.1.62	40 miles S.W. Cape Point	L	2,545 mm
28.1.62	40 miles S.W. Cape Point	L	3,210 mm
30.1.62	30 miles W. Cape Point	L	2,935 mm
30.1.62	30 miles W. Cape Point	L	3,100 mm
30.1.62	30 miles W. Cape Point	L	2,935 mm
30.1.62	30 miles W. Cape Point	L	± 280 kg
25.2.62	30 miles W. Cape Point	T	210 kg
26.2.62	W. Peninsula	L	± 300 kg
7.3.62	W. Peninsula	L	± 300 kg
7.3.62	75 miles W. Cape Point	L	3,460 mm
	Maikaira indica		
30.3.62	W. Slangkop	L	± 150 kg
31.3.62	W. Slangkop	L	± 370 kg
31.3.62	W. Slangkop	L	± 80 kg
20.5.62	N.W. Cape Columbine	L	—
24.1.63	40 miles S. Cape Point	L	3,648 mm
20.2.63	40 miles S. Cape Point	L	645 kg
22.2.63	W. Peninsula	L	2,936 mm
22.2.63	W. Peninsula	L	2,570 mm
2.3.63	W. Peninsula	L	3,025 mm
4.3.63	W. Peninsula	L	2,753 mm
29.3.63	Camps Bay beach	X	2,151 mm
	Makaira nigricans		
1838	Table Bay	X	—
7.6.58	Hout Bay	X	± 225 kg
23.6.61	45 miles N.W. Dassen Isl.	L	2,959 mm
16.4.64	30 miles S.W. Cape Point		3,385 mm
	Tetrapturus audax		
25.2.61	W. Slangkop	L	1,746 mm
25.2.61	W. Slangkop	L	2,182 mm
15.3.61	W. Cape Point	L	± 70 kg
26.1.62	40 miles S.W. Cape Point	L	2,285 mm
1.2.62	W. Peninsula	L	2,120 mm
8.2.62	W. Peninsula	L	2,011 mm
17.2.62	W. Peninsula	L	± 70 kg
22.2.62	30 miles W. Cape Point	[3]L	2,131
22.2.62	30 miles W. Cape Point	L	2,132
22.2.62	30 miles W. Cape Point	L	2,112
7.3.62	W. Peninsula	L	—
7.3.62	W. Peninsula	L	—
17.4.62	S.W. Cape Point	L	± 50 kg
	Tetrapturus albidus		
2.3.61	[4]35 miles W. Slangkop	L	1,918
11.2.62	W. Cape Point	L	± 45 kg
10.5.62	35 miles W. Slangkop	L	± 40 kg
	Tetrapturus pfluegeri		
24.6.63	125 miles N.W. Cape Columbine	L	1,795 mm
13.7.64	33°09′S 16°07′E	[5]X	588 mm

[1] B=bottom trawling, L=longline, T=trolling, X=other (usually standing).
[2] Given as weight or body size (tip of mandible to fork).
[3] *X. gladius* found in stomach of *T. audax*.
[4] *M. indica* and *T. albidus* taken on same set of longline.
[5] Collected with scoopnet at light station.

Subsequent to experimental longlining for tunas in the waters to the west of Cape Town by the South African Museum (Talbot and Penrith, 1962, 1968) and the Division of Sea Fisheries (Nepgen, 1970) at the beginning of 1960, a number of commercial fishing vessels were equipped for longlining. It was hoped that this would provide useful employmen during the fishing offseasons. For a number o reasons this experiment was not a success and wa tried on a large scale only during the years 1961-1964 The boats fished for a company under contract t supply tuna; all other fish landed could be dispose of by the skipper as he wished. There was little or no demand for marlin and skippers were only too pleased to inform the South African Museum when they landed marlin in return for a small commission. There was, however, a strong market demand for broadbill swordfish with the result that these fish were immediately sold on docking to fish dealers and seafood restaurants.

The collection of billfishes examined was not large but was interesting in the number of species that were found to occur in this limited area of water. Apart from the swordfish *(X. gladius)* four species of marlin, the black *(M. indica)*, the blue *(M. nigricans)*, the striped (*T. audax*) and the white (*T. albidus*), and one species of spearfish (*T. pfluegeri*) were obtained from the area during that period.

BILLFISHES RECORDED FROM THE CAPE OF GOOD HOPE

Xiphias gladius

The data for the broadbill swordfish are scanty, especially with regard to longline-caught fish, since it was the only marketable billfish landed. The species does not appear to have any seasonal pattern of appearance off the Cape, occurring at any time of the year. It was caught in a very wide range of sizes and in a number of ways, from a juvenile collected alive in a tidal pool to large specimens taken by longlining. The majority of fish examined were not taken by longlines but by bottom trawlers fishing in water over 100 fathoms deep. It is presumed that the swordfish were feeding on the bottom; in one case a number of semidigested coryphaenoid fishes were found in the gut.

Makaira indica

Black marlin were the most common of the istiophorids off the Cape. They apparently had a very limited season, being found only between the middle of January and the end of March (with one exception). All fish examined were unripe females and of a large size (up to 645 kg). All but one of the fish were taken by longliners.

Tetrapturus audax

Striped marlin were not as common as black; only 13 fish were seen. They appeared to be present in the area at the same time as the black, and also were found only between the middle of January and the end of March. Again there was one exception to this pattern; for this species, and the black marlin, the exceptions were fish caught in 1962. All striped marlin examined were taken by longline.

Tetrapturus albidus

White marlin were rare and only three were taken in the 4 yr under consideration. There is a suggestion that they may appear a little later than the other two species so far discussed, being found from February to May. However, the May specimen was taken in 1962, when the water conditions off the Cape possibly remained suitable for billfishes until later than in

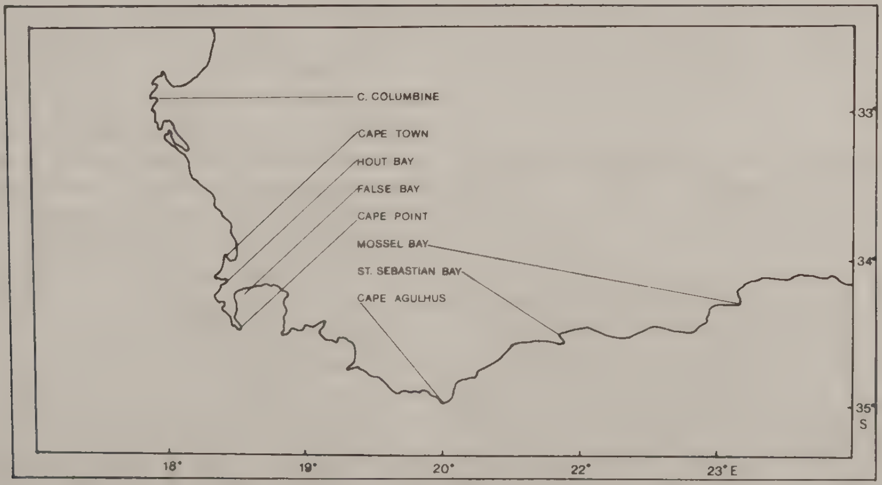


Figure 1.—The Cape of Good Hope.

the other years. All fish were taken by longline west of Cape Point; Smith's (1964) record "off Cape Agulhas" is an obvious error.

Makaira nigricans

Blue marlin, although known from very few specimens, appear to enter the fishery off the Cape at a different time of the year from the other three species. Of the three specimens for which any data are available, one was taken in April, one in June, and one in July. It is extremely interesting to note that the blue marlin did not appear during the summer fishery. This could suggest an Atlantic origin (compare *T. pfluegeri*) rather than an Indo-Pacific origin. It is also interesting that the blue marlin, the only circumtropical istiophorid, was one of the scarcest in the area. This may suggest that there is only limited genetic exchange between the two populations. Smith (1964) has suggested an Indo-Pacific origin for the blue marlins taken off Cape Town on the basis of one fish taken in the same area as a striped marlin. The fish referred to is apparently the fish taken on 23 June 1961 by one of us (M.J.P.); in other words, in the same geographic area as striped marlin (as stated by Smith), but at a different time of year and probably from a different water mass. From temperature and salinity records taken during the tuna cruise on which this fish was landed, it is believed that the fish was taken in water of Atlantic surface origin.

Tetrapturus pfluegeri

The longbill spearfish was the rarest of the istiophorids found during the longline fishery. Only two were seen, an adult and a juvenile, both in midwinter.

BILLFISHES NOT RECORDED FROM THE AREA

Istiophorus

No specimens of the sailfish have been obtained during the Cape longline fishery. There are, however, certain old records. Most can be discarded owing to the wider geographical area covered by the term Cape of Good Hope in 19th century biological reports. De Castelnau (1861), however, described *Histiophorus granulifer* from St. Sebastian Bay, to the east of Cape Agulhas, only just outside the area discussed in this paper. This species has generally been considered to represent a sailfish (Jones and Silas, 1964; Smith, 1964; Nakamura, Iwai, and Matsubara, 1968; Morrow and Harbo, 1969). Reexamination of the type (a rather battered skull and mandible), however, has shown it to be the skull of a *Makaira* rather than an *Istiophorus*. The skull is broad and heavy with a short stout bill. The bill is 799 mm in length, with a circumference of 169 mm at a point level with the anterior tip of the mandible. It is possibly *M. nigricans* but insufficient comparative material was available for us to be certain.

Tetrapturus angustirostris

Although not found at the Cape there is little reason why this species should not occur in the area, at least in some years. It is probably common in the southern Indian Ocean (Japanese fishery records), and has been recorded off Durban (Penrith, 1964).

RECORDS OF BILLFISHES BASED ON JAPANESE CATCHES IN THE AREA

A detailed analysis of the Japanese commercial longline catches of billfishes in the Atlantic has recently been completed (Wise and Davis, 1973). The data given here are based on a shorter period, but include data from the southwest Indian Ocean in addition to the southeast Atlantic. There are problems in using these data, since the catches of spearfish and sailfish are not differentiated and likewise the small marlins, white and striped, are also not distinguished. It is only in the region here discussed, where both small marlins can occur, that their nonseparation will cause any difficulty.

The catch in the waters off southern Africa has been plotted for the common istiophorids by 5° squares on a quarterly basis for the years 1965-69. The results are shown graphically in Figures 2-4. In these figures the catch rates per 100 hooks have been shown for each square by the conventional markings as used on dice and are as following:

1=<0.001
2= 0.001–0.004
3= 0.005–0.009
4= 0.01–0.04
5= 0.04–0.1
6=>0.1

The distribution pattern of black marlin based on these catches is shown in Figure 2. Several features

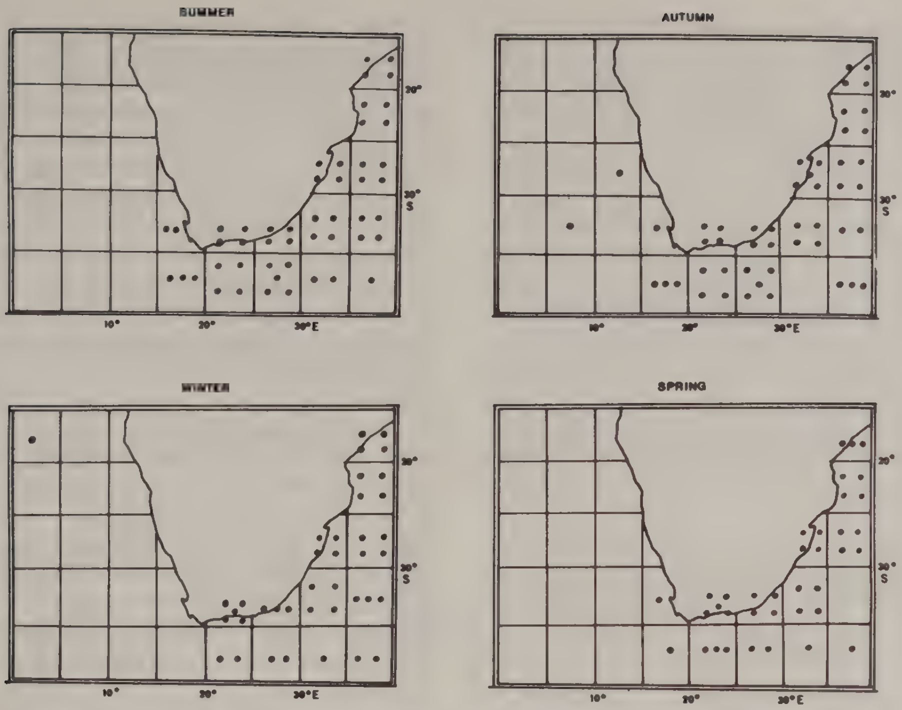


Figure 2.—Distribution of *M. indica* around the southern tip of Africa by quarter of the year. Catch rates (per 100 hooks) represented by number of dots in each 5° square (one—<0.001, two—0.001-0.004, three—0.005-0.009, four—0.01-0.04, five—0.04-0.1, six—>0.1).

e noteworthy. Judging from the catch rates there is ways a fair black marlin population present in the uthwest Indian Ocean. At all times of the year, cept midwinter, a certain number of the fish move to the sea area west and south of the Cape of Good ope, but are apparently most numerous there in the mmer period, January to March.

At various times records of the black marlin are und well into the Atlantic within the area covered the present report. Wise and Davis (1973) have corded catches of this species over a wide area of e Atlantic, but in all cases the records are based on panese catch statistics. Apparently none of the h have been examined by an ichthyologist. On the her hand the skippers of the Japanese boats can be sumed to be familiar with the different marlins and eir distribution and will presumably check any entification as unexpected as this. It has become most a theorem that the black marlin does not cur in the Atlantic, and there is the resultant nger that any large marlins found in the Atlantic ill be identified as blues without adequate examination.

Catch rates west of long. 20°E are never as high as those east of this meridian, but there is a suggestion of a northwesterly movement of the stocks from the southern tip of Africa as summer advances and a withdrawal with the onset of winter. It is suggested that the black marlins present in the Atlantic are fish that have entered the Atlantic in eddies of warm Agulhas water at this time and are then trapped by cold water, preventing their return to the Indian Ocean.

Similar catch statistics have been plotted for the blue marlin. These are shown in Figure 3. On the basis of the very few catches made off the Cape by local vessels, it was thought that the blues were of Atlantic origin. The more widespread catches of the Japanese fishing industry, however, suggests that at least some of the blues may actually be of Indo-Pacific origin. Between January and June there is a widespread but low catch round the southern tip of Africa, but as winter progresses there is apparently a movement of fish away from the Cape, and diffusely distributed fish then resolve into two populations, an Atlantic one and an Indo-Pacific one, although a subpopulation of the Atlantic fish may remain at the Cape during winter on account of the rich food available. The pattern of distribution in summer, however, suggests that there is limited scope for genetic interchange between the two populations. This adds support to the concept of only one worldwide species of blue marlin, but with certain features of a clinal nature. The possibility that the length of the pectoral fin in *T. angustirostris* varies as a cline across the Indo-Pacific has been advanced (Penrith, 1964; Merrett, 1971). It is possible that the degree of development of the lateral line system in the blue marlin is similar, but more marked, since the geographic range is greater, and the Cape of Good Hope, while not a barrier to this species, probably tends to minimize the degree of genetic interchange, and thereby accentuates the development of minor differences.

The catch rates for the category white/striped marlin for summer and winter are shown in Figure 4. From the catch statistics the two species cannot be separated. In view of the records from the same source of black marlin in the Atlantic it must be assumed that occasional striped marlin will also occur in the Atlantic. In summer it can be seen that the Atlantic fish (white marlin) are present all down the west coast, and in the southwest Indian Ocean (striped marlin) high catch rates are general. In winter there are still fish east of long. 20°E but the catch rates have dropped, whereas west of this point the fish have disappeared and are present only in small numbers north of lat. 30°S. Although the distribution for autumn is not shown, it is essentially the same as winter. This confirms the results of the much more limited local South African fishing, namely that these species are present in the Cape of Good Hope area only in summer.

Broadbill swordfish were taken by the Japanese boats at all times of the year in the area. This species was also common farther south than the other species, being taken occasionally south of lat. 40°S. Catch rates for this species were in general higher than for the other species, but were apparently limited by the subtropical convergence.

In the Japanese statistics the spearfishes are not differentiated from the sailfish. It is not possible to

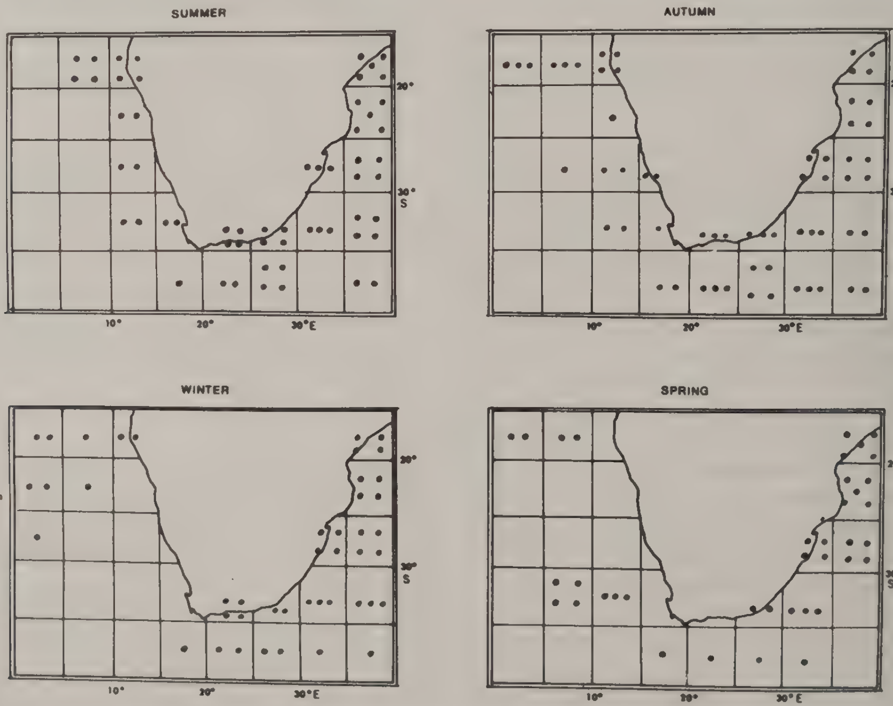


Figure 3.—Distribution of *M. nigricans* around the southern tip of Africa by quarter of the year. Catch rates (per 100 hooks) represented by number of dots in each 5° square (one—<0.001, two—0.001-0.004, three—0.005-0.009, four—0.01-0.04, five—0.04-0.1, six—>0.1).

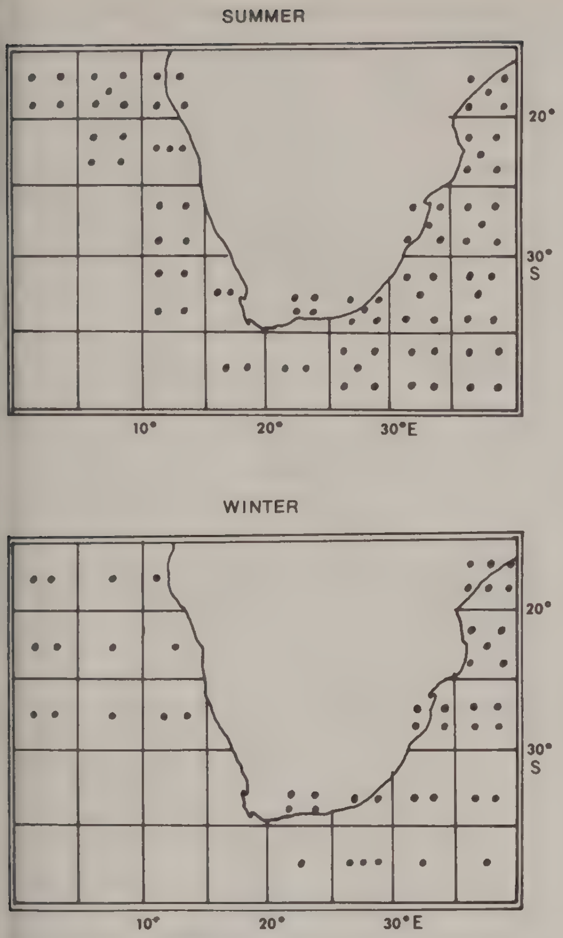


Figure 4.—Distribution of *T. albida*/*T. audax* around the southern tip of Africa, summer and winter. Catch rates (per 100 hooks) represented by number of dots in each 5° square (one—<0.001, two—0.001-0.004, three—0.005-0.009, four—0.01-0.04, five—0.04-0.1, six—>0.1).

attempt any differentiation in the area, although close to the Cape of Good Hope the statistics almost certainly refer to spearfishes. In other areas the majority of fish close to land can be assumed to be sailfish and those offshore to be spearfishes. As has been noted above the sailfish has never been recorded from the Cape of Good Hope area.

HYDROGRAPHY OF THE AREA

Four distinct water masses can be discerned off the southern African coast (see Fig. 10a): the upwelled component of the Benguela Current System (9-16°C and 34.8-35.0⁰/₀₀); the Agulhas Bank mixing water zone of varying composition (16-21°C and 35.2-35.5⁰/₀₀); the Agulhas Current water (22-27°C and 35.4-35.5⁰/₀₀); and the South East Atlantic Surface water (16-21°C and 35.5-35.8⁰/₀₀) (Shannon, 1966).

The upwelled component of the Benguela Current system is a clearly marked coastal low temperature zone originating near the Cape of Good Hope and separated from offshore oceanic water by a steeply gradiented oceanic front (Shannon, 1966; Andrews and Cram, 1969). The frontal system is most strongly defined in summer, during the period of intense local southeasterly winds. The continuous presence of the front is clearly demonstrated as far north as lat. 22° S, near Walvis Bay (Bang, 1971). The nutrient enrichment of surface waters coastward of the front produces rapid production and a high standing crop of phytoplankton which supports the large pelagic fish industry of South Africa.

The Agulhas Bank mixing zone is characterized by systems of eddies, and the structure is very variable (Shannon, 1966). The Agulhas Bank water is the product of mixing by South East Atlantic Surface water and Agulhas Current water. Thus the temperature of this region varies considerably with the seasons between 16° and 21°C depending upon the extent of the contributions of its major sources. The Agulhas Bank water frequently extends to the northwest as a warm current extending around the Cape of Good Hope intensifying the gradients with the upwelled water.

Bang (1970a, 1970b) found that the Agulhas Current movements to the south of Cape Agulhas were dominated by two systems, the Return Agulhas Current and the Westward Extension of the Agulhas Current into the southeast Atlantic (Fig. 5). At about long. 22° E most of the Agulhas Current recurves as the Return Agulhas Current, but a portion is unaffected by this deflection and continues west as tongues of warmer water thrusting into the Atlantic. Shannon (1966) deduced that the northward branching intrusion is likely to move northwards in isolated patches as an anomalous part of the Benguela Current system. Such patches have not been detected north of lat. 32°S and it must be assumed that the patches lose their dynamic integrity and are dissipated by mixing. Darbyshire (1964) and Shannon (1966) agree that the maximum flow of the Agulhas Current is in April (late summer) and the minimum in August (spring). Thus the maximum westward

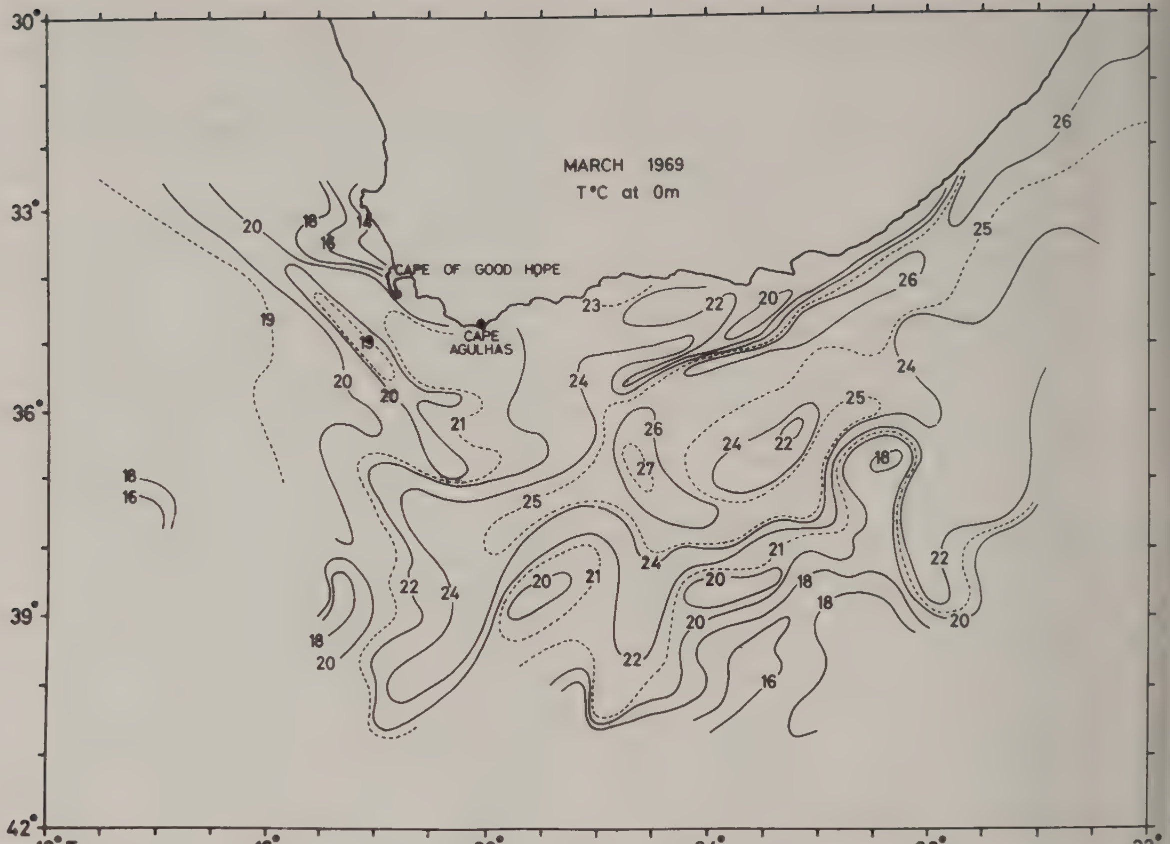


Figure 5.—Surface temperatures off South Africa, March 1969 (from Bang, 1970b).

penetration is in late summer, the minimum in spring, although such penetration could occur at any time of the year.

The South East Atlantic Surface water frequently extends across the Agulhas Bank under the influence of the westerlies in winter. Surface currents then are frequently southerly along the west coast and easterly over the Agulhas Bank. During summer, the South East Atlantic Surface water can frequently be observed as an intrusion between the upwelled component of the Benguela Current System and an Agulhas extension. Figure 10a shows a large intrusion of South East Atlantic Surface water extending over the Agulhas Bank, while Figure 5 shows a thin lens of such water along the edge of the Bank, being outflanked by a northwesterly arm of the Agulhas Current. With the seasonal interplay of northwesterly and southeasterly winds the penetration of South East Atlantic Surface water will vary to a greater or lesser extent. Duncan and Nell (1969) report that between Cape Agulhas and the Cape of Good Hope the summer flow is strongly east to west, and in winter the flow is reversed and weaker.

DESCRIPTION OF OCEAN CONDITIONS DURING THE SURVEY PERIOD

Summer, January 1961

(Shannon, 1966; Fig. 6a,b)

The Agulhas Current (>22°C and 35.4-35.5‰), extends over a considerable portion of the Agulhas Bank, reaching close inshore in the Cape Agulhas region. In addition, the Current extends around the Agulhas Bank and penetrates to the northwest up to about 32°S, the core of the warm-water extension being 150 nautical miles offshore. An isolated eddy of northward travelling Agulhas water is notable at lat. 36°S. South Atlantic Surface water is confined to the west of long. 15°E, that is greater than 200 nauti-

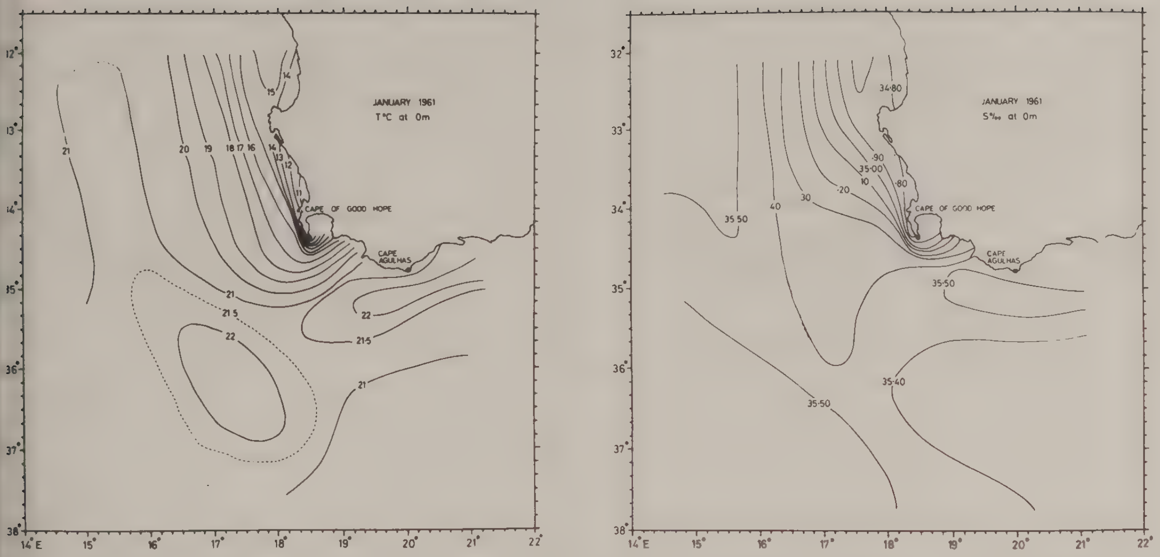


Figure 6.—Surface temperatures and salinities off South Africa, January 1961 (from Shannon, 1966). A. Temperature. B. Salinity.

cal miles west of the Cape of Good Hope. Typical Agulhas Bank mixed water is present as a small patch of high salinity water (35.5‰). The upwelling component of the Benguela Current system is present to shoreward of a well-defined front.

As westward penetration of the Agulhas Current is pronounced, Indo-Pacific billfishes could be encountered as far west as long. 15°E and up to lat. 32°S. Close inshore, on the west and south Cape coast, the abundance of pelagic fish in the 14-16°C upwelled-origin water may be some inducement to feeding. No South East Atlantic Surface water approaches the coast.

Autumn, April 1961

(Fig. 7a,b)

The Agulhas Current Extension is well marked, extending as an intrusion of 22-24°C and 34.4‰ water to lat. 36°S, in a northerly direction. The Agulhas Bank mixed water is continuous from east of the Bank, round the Cape of Good Hope and into the South East Atlantic. The South East Atlantic Surface water is, for the most part, west of long. 17°E. The frontal system between the ocean and the upwelling area is not well defined, although the low temperatures indicate that upwelling is occurring (13°C and 34.8‰). The continuous low temperature and salinity area (15°C and 34.9‰), extending around the Cape of Good Hope eastwards towards Cape Agulhas, indicates that either upwelling has been occurring or a southeasterly drift has occurred.

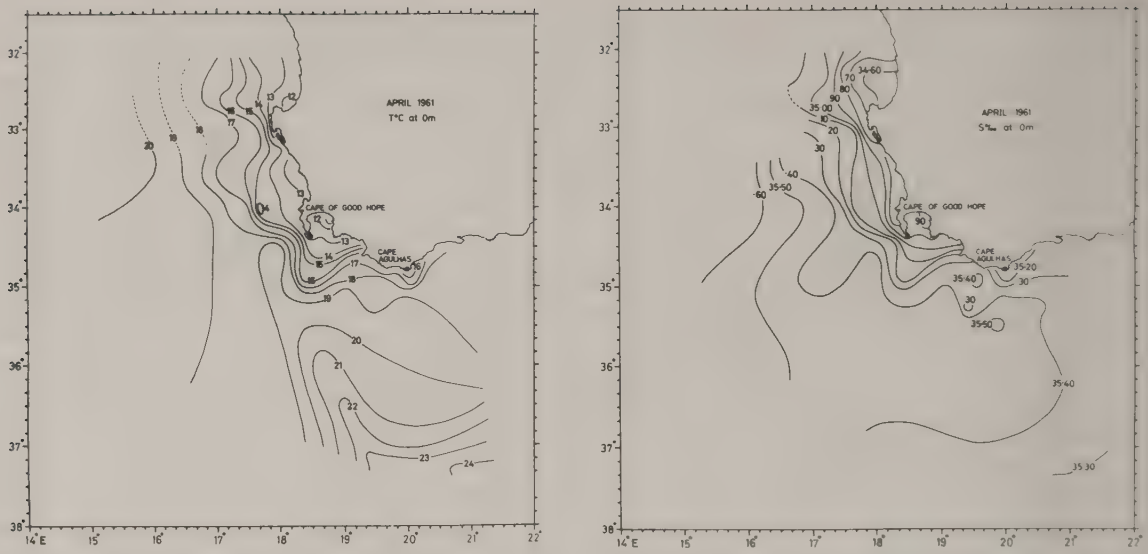
At 20 m the isopleths tend to follow the coastline, except that the influence of the Agulhas intrusion, 21°C and 34.45‰, and South East Atlantic Surface water, 19°C and 35.6‰, can be observed. At 100 m the isopleths tend to follow the coastline.

The possibility of billfishes approaching the coast at this time is not high. The extension of the Agulhas Current exists 120 nautical miles south of the Cape of Good Hope and the South East Atlantic Surface water about 100 nautical miles west of the Cape. If Indo-Pacific billfishes have moved into the Agulhas mixed water, the continuous westward extending area offers a route to the west passing close along the south and west Cape coasts, although the temperature and salinity of this area may be uncomfortably low, and therefore unsuitable for billfishes. As in high summer, little opportunity is extended for the movement of southeast Atlantic billfishes eastwards around the Cape.

Winter, July 1961

(Fig. 8a,b)

The survey area is dominated by the South East Atlantic Surface water, which extends to the east of Cape Agulhas. There is only slight evidence of the


APRIL 1961
T°C at 0m
APRIL 1961
S‰ at 0m
CAPE OF GOOD HOPE
CAPE AGULHAS
14°E
15°
16°
17°
18°
19°
20°
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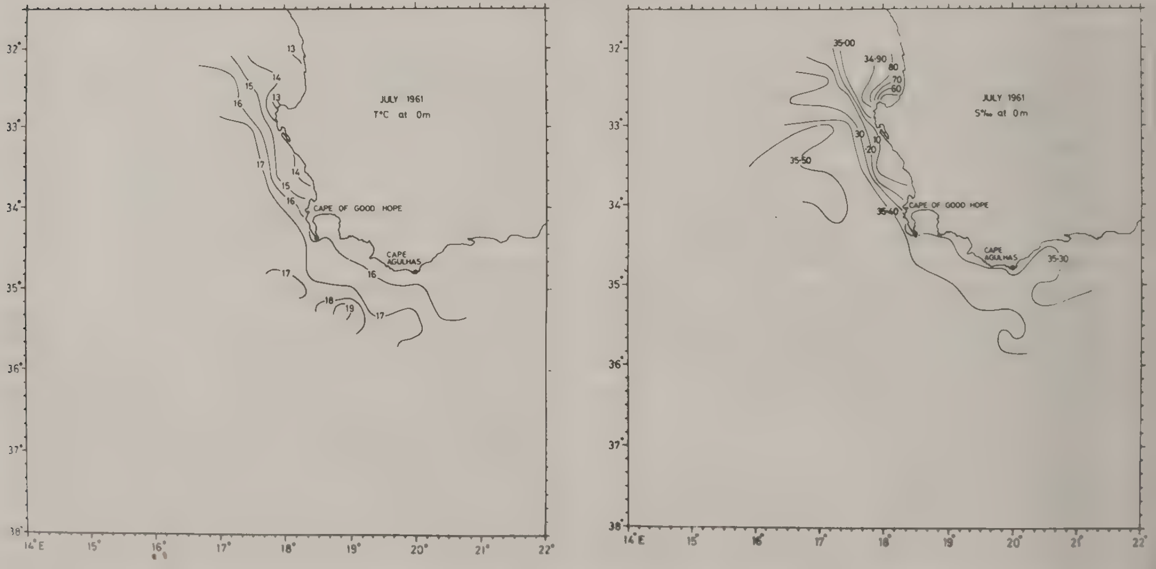
36°
37°
38°

Figure 7.—Surface temperatures and salinities off South Africa, April 1961. A. Temperature. B. Salinity.


JULY 1961
T°C at 0m
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37°
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Figure 8.—Surface temperatures and salinities off South Africa, July 1961. A. Temperature. B. Salinity.

upwelled component of the Benguela Current system (<14°C and <35.1‰) and the Agulhas Bank mixed water is absent. A similar pattern exists at both 20 and 100 m.

At this time, southeast Atlantic billfishes could extend their range to the east of Cape Agulhas and could also be located close inshore on the Cape coast. Owing to the absence of any identifiable Agulhas Current water it is unlikely that any Indo-Pacific billfishes would be resident in the survey area.

Late spring, October 1961
(Fig. 9a,b)

The winter eastward penetration of the South East

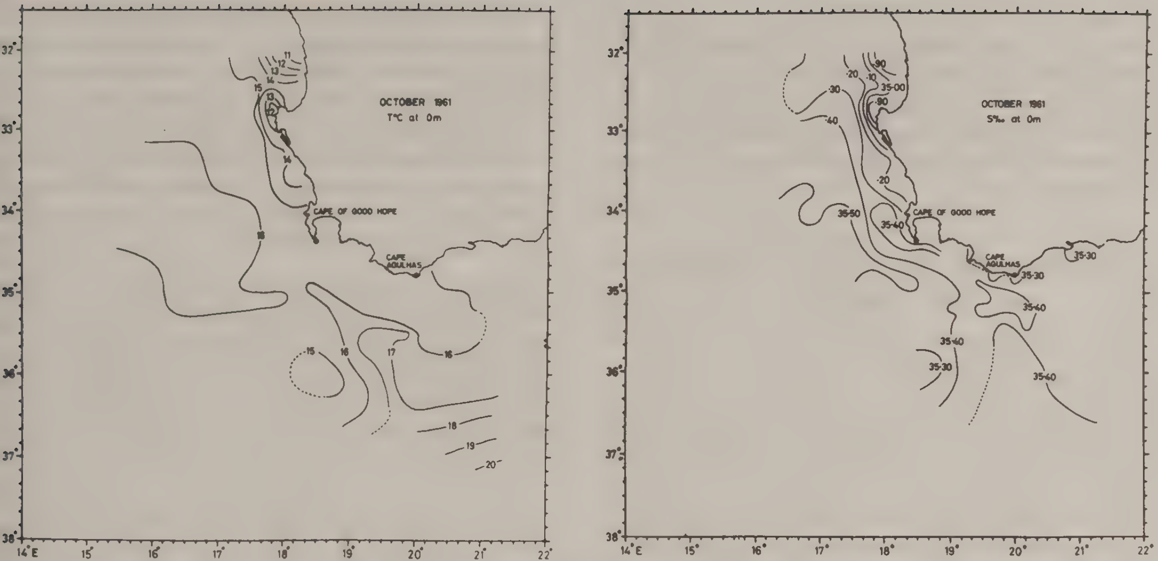

Figure 9.—Surface temperatures and salinities off South Africa, October 1961. A. Temperature. B. Salinity.

Atlantic Surface water is being reduced by the reassertion of the Agulhas Current's westerly extension (>20°C and 35.4‰) and the formation of a distinct Agulhas Bank mixed water zone. The Agulhas extension is mild and extends only to lat. 37°S, some 140 nautical miles from the coast. However, the Bank water is well marked (<16°C and >35.4‰) on the Bank itself, and also shows an interesting high salinity intrusion (>35.4‰) round the Cape of Good Hope up to lat. 34°S. The South East Atlantic Surface water is present at long. 18°E although remaining more than 40 nautical miles offshore. At 100 m, the presence of the South East Atlantic Surface water is more strongly felt and it extends eastward to nearly long 20°E. A portion of the Agulhas Return Current is present on the eastern edge of the Bank as part of a powerful eddy, similar to "eddy A" described by Bang (1970b).

Despite the reestablishment of the Agulhas Current in the survey area, the contribution of the Indo-Pacific fauna is likely to be small. The tongue of Agulhas Bank mixed water which extends around the Cape of Good Hope may allow Indo-Pacific billfish to move west, but the limited westward penetration of the Agulhas Current itself makes this occurrence less likely. The South East Atlantic Surface water dominates the remainder of the survey area, bringing with it the strong likelihood of Atlantic billfish occurrence farther offshore than 40 nautical miles. Thus in this period there is a strong possibility of both Atlantic and Indian Ocean forms being present, but with more chance of Atlantic species.

Summer, January 1962

(Fig. 10a,b)

Surface conditions at this time give an excellent example of the interplay between the four water masses off southern Africa. The Agulhas Current is present as a coastal tongue east of long. 21°E, contributing to the Agulhas Bank mixed water, and as a strong westward extension south of lat. 36°S. The Agulhas Bank water is clearly defined (<20°C and <35.5‰) and extends from the coastward portion of the Bank westwards around the Cape of Good Hope, where it creates a dramatically steep gradient with the upwelled water. Between the Agulhas Bank water and the Agulhas Current Extension is a large intrusion of South East Atlantic water which extends across the southern portion of the Agulhas Bank. At 20 m the continuity of the Agulhas Bank mixed water around the Cape of Good Hope is very clearly marked.

Thus an interesting situation prevails: Indo-Pacific billfishes could be present either close inshore between the Agulhas Bank and around the Cape of Good Hope to lat. 33°S or south of lat. 36°S, in the Agulhas Extension. Between these areas the likelihood of Atlantic billfish occurrence is high, with particular interest in the fact that the South East

Atlantic water occurs within 20 nautical miles of the coast at the Cape, "compressing" the Agulhas Bank water against the upwelled water. In this particular summer season, therefore, one would expect all species of billfishes to occur within the survey area in reasonable numbers in the well-defined interwoven oceanic areas.

SUMMARY OF POTENTIAL BILLFISH MOVEMENT

East-west movement is possible by two methods. Firstly, billfishes could be present in the Agulhas Extension which curves northeastward into the South East Trade Wind drift, west of the Benguela Current system. This extension could become isolated and move farther north as an eddy until its identity is lost through mixing. Secondly, billfishes could become involved with the Agulhas Bank mixed water when its temperature is suitable and move westward in the nearshore current around the Cape of Good Hope, to seawards of the front between the ocean and the upwelling area. East-west movements would be assisted in late summer by the maximal westward penetration of the Agulhas Current (Fig. 2 suggests that this may occur), and inhibited in winter when the Agulhas penetration is at a minimum.

Movement from west to east could also be encouraged in two ways: firstly, with the assistance of the eastward intrusion of South East Atlantic Surface water extending onto or near the Agulhas Bank; secondly, by the close inshore movements of water in a southerly or easterly direction round the Cape of Good Hope and along the south coast. Both these water movements are considerably enhanced during winter and correspondingly diminished or absent during summer. In winter, however, billfishes appear to be rare in the southeast Atlantic.

Thus two patterns emerge: the possibility of a long-term or a short-term residence in alien water. The long-term residence could be caused by a westward movement in the Agulhas Extension or inshore current during summer followed by a period of residence in the southeast Atlantic, possibly feeding on pelagic fish at the edge of the upwelling area. Later, in winter, an eastward movement would commence in the South East Atlantic Surface water as it pushes towards the Agulhas Bank. The short-term residence is possible by a similar mechanism, but accepts no delay before the fish take advantage of the common South East Atlantic Surface water intrusion to return eastwards. Naturally, the inverse applies to Atlantic billfishes extending into the Agulhas region, but appears unlikely to take place; the wider coverage of the Japanese fishery suggests that the blue marlin and the longbill spearfish, *T. pfluegeri*, caught off the Cape at this time are attracted by the rich feeding and will not move further east.

This much can be deduced from available data.

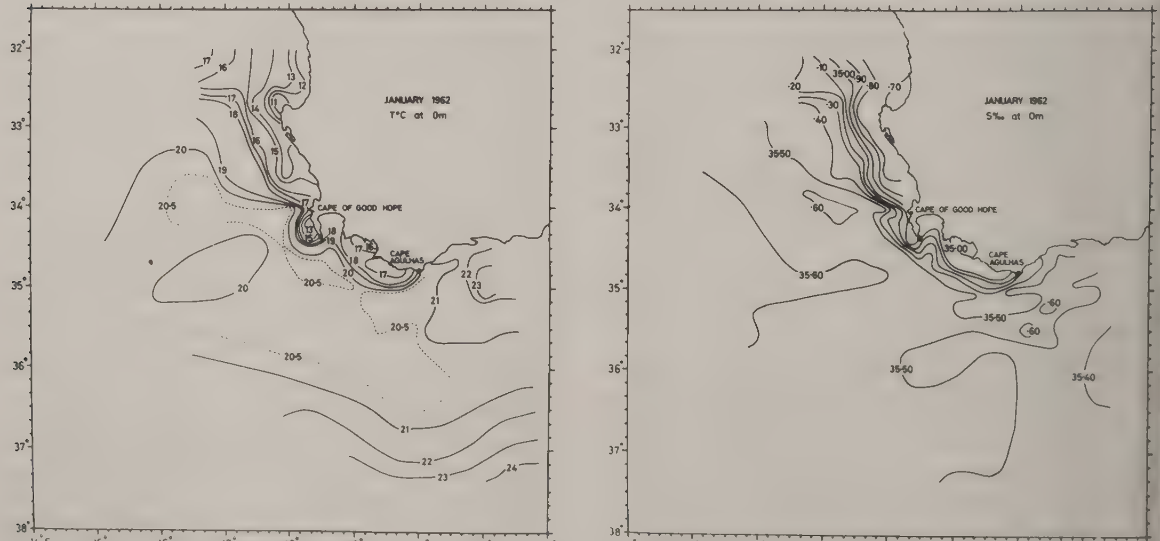

Figure 10.—Surface temperatures and salinities off South Africa, January 1962. A. Temperature. B. Salinity.

eculation suggests that the bulk of the Agulhas una is carried into the Return Agulhas Current; us the number of billfishes following a northwest-ard extension would be relatively few, and then th a maximum occurrence in late summer. Cor-spondingly, the bulk of the southeast Atlantic bill-h would follow the South Atlantic gyre. A few uld find their way into the intrusion off South rica, but this would occur in winter when they are e in the area.

Why this possible movement between the two ean systems has been so little utilized by billfishes d other large oceanic fishes such as the tunas) is t known. That it has been little used is certain; til very recently it was not known to occur at all in iophorids (with the exception of the blue marlin). e can only suggest, in the light of present knowl-ge, that some innate behavior pattern, possibly as result of hydrographic conditions in the earlier tory of the area, is responsible, since there is no vious physical barrier. The Cape of Good Hope is t unique in acting as an inexplicable barrier; the aits of Gibraltar are apparently not a marked ogeographical barrier (Ekman, 1953), but as far as esent knowledge goes, appear to act as a similar rrier to the Mediterranean spearfish, *T. belone*.

ACKNOWLEDGMENTS

We owe a debt of gratitude to many persons for ir help: to C.R. Robins, R.S. Shomura, F.H. lbot, and J.P. Wise, we are grateful for their ompt and patient answers to our queries; to S. uins, B.J. Pretorius and C.S. de V. Nepgen for p in obtaining literature and to T. Blamire, who s responsible for the extraction and plotting of the drographic data from the log sheets.

Our grateful thanks are due to F. Williams, not y for agreeing to read the paper at the interna-nal Billfish Symposium on our behalf, but also for help in providing information relating to the large agic fishes to one of us (M.J.P.) over many years, h little in return.

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Catch Distribution and Related Sea Surface Temperature For Striped Marlin *(Tetrapturus audax)* Caught off San Diego, California

JAMES L. SQUIRE, JR.[1]

ABSTRACT

Records for 4,535 marlin landed at San Diego, California, and related sea surface temperature data were examined for the period 1963 through 1970 to determine time-space distribution and the relationship of catch and sea surface temperatures. For the period 1963 through 1970 the catch of 4,535 marlin was compared to sea surface temperature conditions relative to increased catches.

Catch distribution based on 1963 to 1967 data showed that 76.4% were caught within a 35- by 40-nautical-mile area off San Diego, with the maximum catch being made from mid-August to mid-September. Catch temperatures off southern California calculated for this area from airborne infrared sea surface temperature survey data ranged from 61° F (16.1°C) to 73° F (22.8°C); the mean catch temperature was 67.8° F (19.9°C).

Sea surface temperature conditions based on 2-week average temperature charts issued by the National Marine Fisheries Service indicate that an initial warming of water to an average temperature of 68° F (20.0°C) or above is related to an increase in catch. When average temperatures were below 68° F (20.0°C), 931 fish were caught; between 68° (20.0°C) and 70° F (21.1°C) the catch was 1,886 fish; and a further increase to 70° F (21.1°C) or above resulted in a catch of 1,718 fish.

Catch data and isotherm charts, 1963 through 1970, indicate that the continuity of the 68° F (20.0°C) and 70° F (21.1°C) isotherms from off central Baja California to off southern California is associated with improved fishing. When these isotherms were discontinuous the average catch per biweekly period was 82.0 fish; when these isotherms were continuous the average catch was 146.1 fish. The highest average catch per biweekly period (205.3 fish) was recorded when the 70° F (21.1°C) isotherm was continuous.

The striped marlin *(Tetrapturus audax)* is the object of a sport fishery in southern California waters during late summer and early fall. Sport fishing for striped marlin in these waters has been conducted since about 1903 (Howard and Ueyanagi, 1965) and striped marlin were caught commercially up to 1937. Since 1937 it has been illegal to land the species commercially in California. The early sport and commercial fishery was centered near Catalina Island and between the island and the mainland. In recent times the area off San Diego has experienced increased angling effort, and presently this area yields the largest number of sportcaught striped marlin. Most of the marlin are landed at three points in southern California: the Avalon Tuna Club, Avalon, Catalina Island; the Balboa Angling Clu Newport Beach; and the San Diego Marlin Clu San Diego. At these clubs each fish is weighed a information is recorded on a weight slip (Fig. 1).

Changes in sea surface temperature affect the d tribution of many pelagic marine fishes commo caught off southern California. During periods high temperatures, greater numbers of the more i portant marine game species, such as Pacific bon *(Sarda chiliensis)*, yellowtail *(Seriola dorsalis)*, a Pacific barracuda *(Sphyraena argentea)*, which common to the lower west coast of Baja Califor Mexico, migrate northward into higher latit (Hubbs, 1916, 1948; Walford, 1931). Fishing s cess for albacore *(Thunnus alalunga)* off this a has been related to changes in sea surface temp ture (Hester, 1961; Clemens and Craig, 19 Radovich (1961, 1963) has also described the eff

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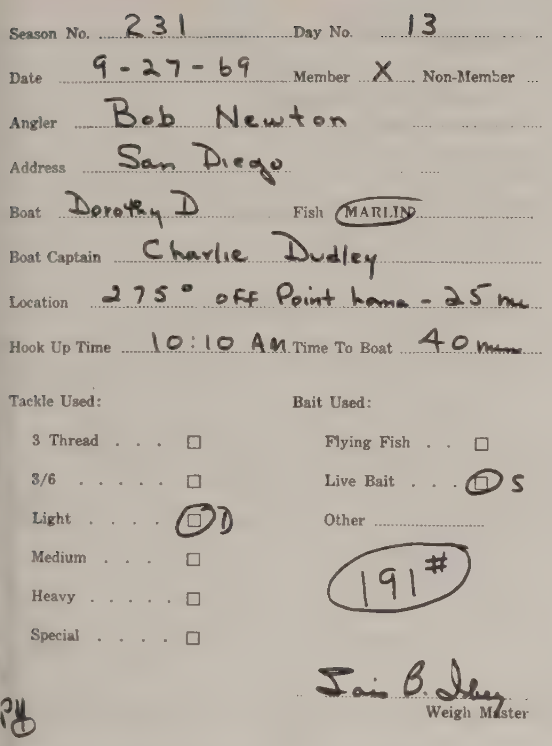
[1] National Marine Fisheries Service, Southwest Fisheries Center, La Jolla Laboratory, NOAA, La Jolla, CA 92037.



Season No. 231 Day No. 13

Date 9-27-69 Member X Non-Member

Angler Bob Newton

Address San Diego

Boat Dorothy D Fish [✓ MARLIN]

Boat Captain Charlie Dudley

Location 275° off Point Loma - 25 mi

Hook Up Time 10:10 AM Time To Boat 40 min

Tackle Used:

3 Thread . . . ☐

3/6 . . . . . . ☐

Light . . . . ☑ D

Medium . . . ☐

Heavy . . . . . . ☐

Special . . . . . ☐

Bait Used:

Flying Fish . . ☐

Live Bait . . . ☑ S

Other

191#

Weigh Master

Figure 1.—Weight slip used by the San Diego Marlin Club, San Diego, California.

of water temperature on the distribution of scombrid fishes common to the water off southern California and Baja California.

There are many physical and biological factors that can affect the distribution of fishes. Temperature, salinity, turbidity, and food supply (plankton and forage species) are but a few of these factors. However, knowledge of the precise degree to which one or a combination of factors affect distribution is not known. Temperature as one of the easily measured factors has been shown in some instances to affect distribution of organisms.

Observations of sea surface temperature prior to and immediately after the start of good fishing might give us some clues as to thermal conditions that may be contributing to successful striped marlin fishing. In this paper the temporal and geographical distribution of striped marlin catches off San Diego from 1963 to 1967 are described, and the relation of surface water temperature to fishing success during the period 1963 to 1970 is examined.

Since more striped marlin were landed at the San Diego Marlin Club than at any other location, I used their catch records to determine the geographical distribution of the catch for each month of the fishing season. These records provided catch location for 3,923 fish, but the fishing effort expended in catching this amount of fish is not known. These catch distribution data and sea surface temperature data derived from airborne temperature surveys were used in the calculation of the average or mean catch temperature off San Diego for all striped marlin caught during the major months of fishing for the years 1963 through 1967.

The cooperation of the San Diego Marlin Club in allowing use of its catch records is appreciated.

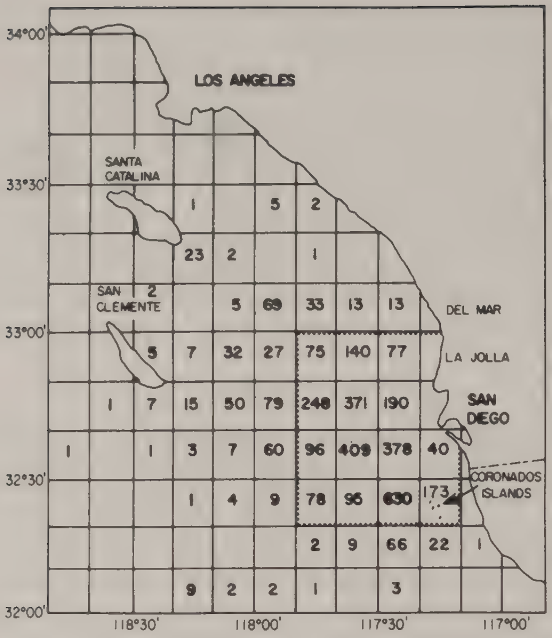
CATCH DISTRIBUTION

The temporal catch distribution for the 1963 to 1967 period is shown in Table 1. Catch records indicate that August, September, and October are the months having the major catches of striped marlin. Few are caught in July, and usually the November catch is minor. Most fish are caught between mid-August and mid-October, with fishing during the first half of September yielding more catch than any other half-month period. Peak annual catches were recorded for every biweekly period, 16-31 August through 1-15 October, for the years 1963 to 1967.

Table 1.—Striped marlin catch landed at the San Diego Marlin Club during half-month periods, July-November, 1963-1967

Month	1st half	2nd half	Monthly total
July	0	31	31
August	163	841	1,004
September	1,279	612	1,891
October	450	250	700
November	297	0	297
		Total	3,923

For the months of August, September, and October, catch locations of striped marlin were plotted on a chart divided into block areas of 10-minute latitude by longitude dimension. These areas are identical to the block area system used by the California Department of Fish and Game for determining catch locations for commercial and party boat catches (Young, 1963). The total catch over the 5-yr period by block area is shown in Figure 2, and the catch for each month is shown in Figures 3-5. Figure 2 shows that the major fishing area off San Diego outlined by a dark border can be described as being within the boundaries of lat. 32°20′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LOS ANGELES
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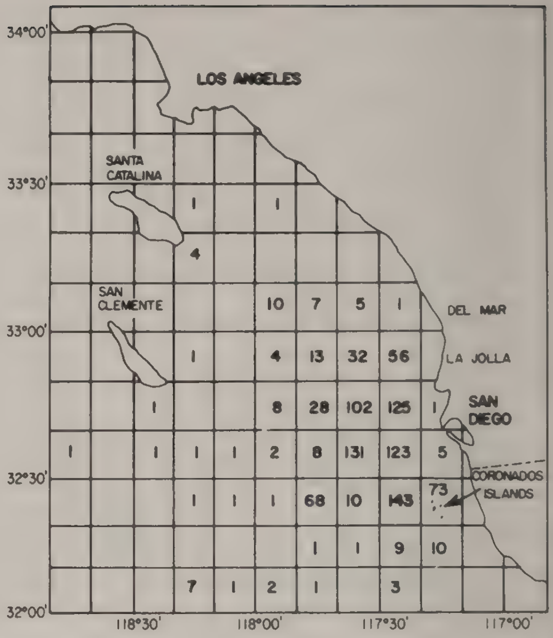
SAN CLEMENTE
DEL MAR
LA JOLLA
SAN DIEGO
CORONADOS ISLANDS
1 5 2
23 2 1
2 5 69 33 13 13
5 7 32 27 75 140 77
1 7 15 50 79 248 371 190
1 1 3 7 60 96 409 378 40
1 4 9 78 95 630 173
2 9 66 22 1
9 2 2 1 3

Figure 2.—Catch distribution of striped marlin landed at San Diego, California; August, September, and October 1963 through 1967.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LOS ANGELES
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SAN CLEMENTE
DEL MAR
LA JOLLA
SAN DIEGO
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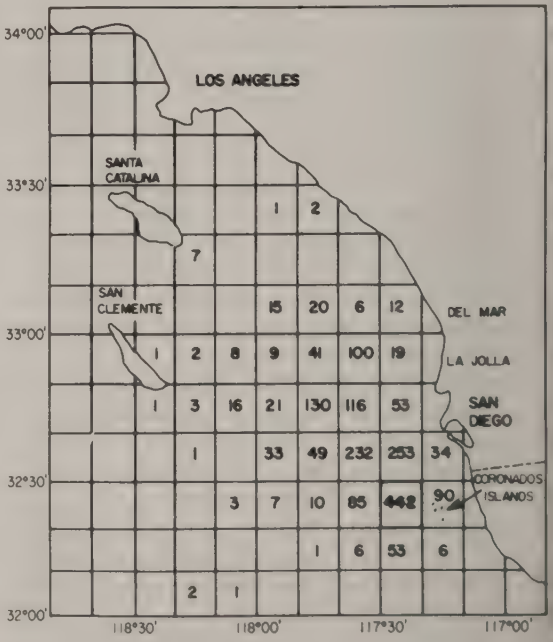
1 1
4
10 7 5 1
1 4 13 32 56
1 8 28 102 125 1
1 1 1 1 2 8 131 123 5
1 1 1 68 10 143 73
1 1 9 10
7 1 2 1 3

Figure 3.—Catch distribution for August 1963 through 1967.

and lat. 33°00′ N, long. 117°50′ W, and the coast from near Del Mar, California, to Rosarita Beach, Baja California, Mexico. This area accounted for 76.4% of all fish landed in these months at the San Diego Marlin Club.

CATCH AND TEMPERATURE RELATIONSHIP

Since August 1963, the National Marine Fisheries Service, Tiburon Coastal Fisheries Research Laboratory, Tiburon, California, has conducted once each month sea surface temperature survey flights off southern California in cooperation with the U.S. Coast Guard. These surveys are conducted from an aircraft using an infrared radiation thermometer (ART) to measure sea surface temperatures (Squire, 1972), and data are published in the form of isotherm charts. Comparison of 146 simultaneous sea surface temperature observations between the airborne instrument and a sea surface bucket cast showed an average difference of 0.35° F (0.2° C) (ART lower), a range of −1.9° F (1.1° C) to 1.2° F (0.7°C), and a standard deviation of 0.65° F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LOS ANGELES
SANTA CATALINA
SAN CLEMENTE
DEL MAR
LA JOLLA
SAN DIEGO
CORONADOS ISLANDS
1 2
7
15 20 6 12
1 2 8 9 41 100 19
1 3 16 21 130 116 53
1 33 49 232 253 34
3 7 10 85 442 90
1 6 53 6
2 1

Figure 4.—Catch distribution for September 1963 through 1967.

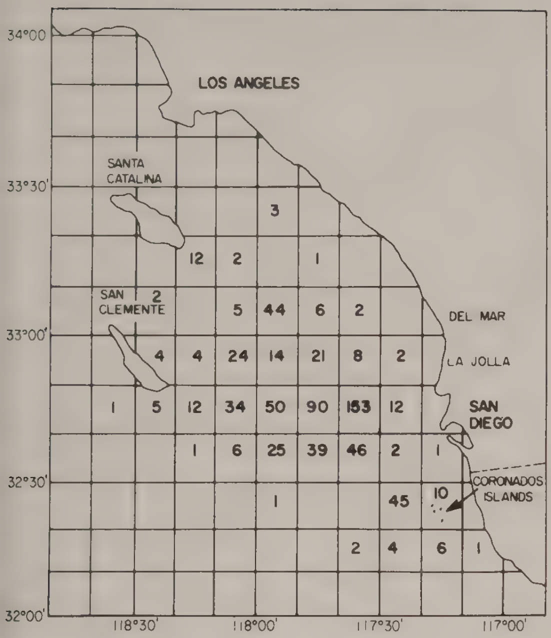

Figure 5.—Catch distribution for October 1963 through 1967.

Table 2.—Mean catch temperatures and numbers of striped marlin landed at the San Diego Marlin Club; August, September, October 1963 through 1967. Mean temperatures calculated from subjective temperature data and catch data for each 10-minute longitude by latitude block area.

Month	Year	Mean temp/month	# fish
August	1963	67.7° F (19.8°C)	605
	1964	68.0° F (20.0°C)	78
	1965	64.1° F (17.8°C)	25
	1966	71.2° F (21.8°C)	102
	1967	66.3° F (19.0°C)	194
September	1963	67.8° F (19.0°C)	717
	1964	69.3° F (20.7°C)	361
	1965	65.0° F (18.3°C)	124
	1966	67.0° F (19.4°C)	335
	1967	69.1° F (20.8°C)	354
October	1963	72.2° F (22.5°C)	73
	1964	66.5° F (19.1°C)	339
	1965	65.2° F (18.4°C)	147
	1966	69.0° F (20.8°C)	98
	1967	67.9° F (19.9°C)	43

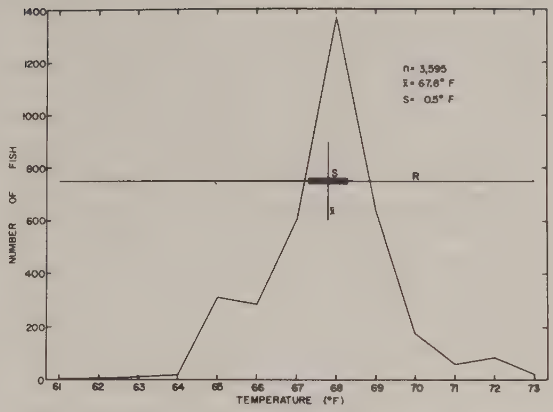

Figure 6.—Distribution of striped marlin catch by sea surface temperature showing the mean ($\bar{x}$), standard deviation (S), and range (R) of temperatures for all catches landed at the San Diego Marlin Club, California (1963-1967).

(0.36° C). From these isotherm charts a sea surface temperature value was estimated for each 10-minute block area where fish were caught as shown in Figures 3-5. Using these temperature data and the catch distribution data for the 10-minute block area, mean catch-temperature[2] figures were computed for striped marlin landed in August, September, and October for the period 1963-1967 (Table 2). Mean catch-temperatures by month for all fish landed were: August, 67.8° F (19.9° C); September, 68.0° F (20.0°C); and October, 67.3° F (19.6°C). Temperatures at which striped marlin were caught ranged from 61.0° F (16.1° C) to 73.0° F (22.8° C) with a mean overall catch temperature of 67.8° F (19.9° C) and a standard deviation of 0.5° F (0.9° C). The distribution of the catch relative to temperature for all catches is shown in Figure 6.

OBSERVATIONS OF TEMPERATURE ISOTHERMS OFF SAN DIEGO AND BAJA CALIFORNIA RELATIVE TO FISHING SUCCESS

For comparison of marlin catch to sea surface temperature for the period 1963 to 1970, temperature data for the area from southern California to off the central west coast of Baja California were obtained from half-month average sea surface isotherm charts published by the National Marine Fisheries Service (U. S. Bureau of Commercial Fisheries, 1961). These isotherm charts are computed from sea surface temperatures reported by ships in the eastern Pacific. From examination of these isotherm charts temperatures off San Diego and to the south toward central Baja California were highest during the fishing seasons of 1963 and 1967, and lowest during the 1965 season (catches of 1,410, 602, and 296 respectively).

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[2] Each striped marlin had a temperature value associated with it; the mean catch-temperature was computed by summing the temperature values and dividing by the total number of entries.

Of particular interest to fishermen is the time of the beginning of the fishing season. Early in the fishing season off San Diego during the period prior to an increase in sea surface temperature to 68° F (20.0°C) the total number of marlin caught was 115, 2.5% of the total catch of 4,535 fishes (1963-1970), whereas for the first half-month period of each year showing the 68° F (20.0° C) isotherm off San Diego. the catch totaled 824 fish, representing an increase to 18.2% of the total catch.

During the half-month periods, data show that temperatures were below 68°F (20.0° C) for 23 periods, and during this time a total of 931 fish, or an average of 40.5 fish/period, were caught. Temperatures were between 68° F (20.0° C) and 69.9° F (21.0° C) during 15 periods, and 1,886 fish were caught, resulting in an average catch of 99.2 fish/period. Temperatures of 70° F (21.0° C) or above for 14 periods resulted in a catch of 1,718 fish or an average catch of 122.7/period.

The numbers of marlin caught during the half-month periods when the 68° F (20.0° C) and 70° F (21.0° C) isotherms were continuous from off Baja California northward to off southern California were compared to the catch when these isotherms were discontinuous (Table 3). For examples of continuous and discontinuous isotherms in the area of study, see Figure 7.

Data show that during periods when the 68° F (20.0° C) or 70° F (21.1° C) average isotherms were continuous from off central Baja California northward to off southern California, a total of 2,046 fish was caught for an average catch/period of 146.1 fish, whereas a total of 1,599 fish was caught for an average catch of 82.0/period when these isotherms were discontinuous. During periods when the 70° F (21.1° C) average isotherm was continuous the largest catch per any period (570 fish) and the highest average catch rate/period (205.3 fish) was recorded.

Table 3.—Comparison of catch and catch rates during periods of continuous and discontinuous 68° (20.0°C) and 70° F (21.1°C) isotherms.

	68°F (20.0°C)	70°F (21.1°C)	Totals
Discontinuous Isotherms			
Catch	1,072	486	1,559
No. of periods	11	8	19
Av. catch/period	97.4	61.7	82.0
Continuous Isotherms			
Catch	814	1,232	2,046
No. of periods	8	6	14
Av. catch/period	101.7	205.3	146.1

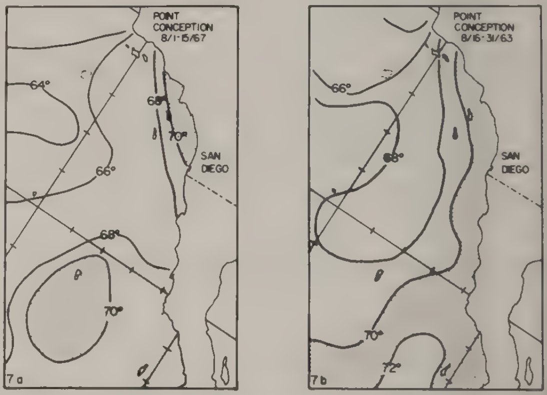

Figure 7.—Examples of discontinuous isotherms (7a) and continuous isotherms (7b) in the area of study.

From examination of the temperature structure of the waters off northern Baja California and southern California based on half-month average temperature charts it appears that 1) initial warming of the waters to an average temperature of 68° F (20.0° C) is related to an increase in catch, 2) continuity of the 68° F (20.0° C) or 70° F (21.1° C) average isotherms from off central Baja California northward to off southern California was associated with higher catches compared to catches when these isotherms were discontinuous.

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Results of Sailfish Tagging in the Western North Atlantic Ocean[1,2]

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and H. LAWRENCE CLARK[4]

ABSTRACT

Migrations of sailfish, *Istiophorus platypterus* (Shaw and Nodder), in the western North Atlantic Ocean are discussed on the basis of results of three cooperative tagging programs. The Rosenstiel School of Marine and Atmospheric Sciences (formerly Institute of Marine Science, and Marine Laboratory) of the University of Miami marked and released 1,259 sailfish between 1950 and 1958 and nine tags were returned. Members of the Port Aransas (Texas) Rod and Reel Club marked and released 515 sailfish between 1954 and 1962 and obtained three returns. The Cooperative Game Fish Tagging Program of the Woods Hole Oceanographic Institution has marked and released 12,525 sailfish between 1954 and May 1972, with 97 tags being returned.

The majority of the returns showed limited movements; most were between localities along the southeast coast of Florida and the Florida Keys. The longer migrations did not follow a distinct pattern, but many of them showed a tendency toward movements between tropical waters (northeast coast of South America, the Lesser Antilles, and the Straits of Florida) in the cold season and temperate waters (the Gulf of Mexico and the United States coast between Jacksonville, Florida and Cape Hatteras, North Carolina) in the warm season.

Times at liberty, which ranged from less than 1 day to over 4 yr, with only nine exceeding 18 mo, are generally consistent with earlier findings that the sailfish is a short-lived species. Tag returns give no indication of heavy commercial fishing pressure on the stocks under study.

Sailfish have been tagged and released in the western North Atlantic Ocean more or less continuously since 1950 through the cooperation of sport fishermen. Tagging was undertaken in order to study sailfish migrations and populations, as well as their mortality and growth rates. Another objective was to learn whether enough sailfish survive capture to justify releasing them for purposes of conservation. Earliest efforts were designed to determine the feasibility of tagging, and the best methods and equipment for the purpose.

The fish were tagged by cooperating sport fishermen with equipment supplied by three agencies—the Rosenstiel School of Marine and Atmospheric Science (RSMAS) (formerly the Institute of Marine Science, and also the Marine Laboratory) of the University of Miami, Florida; the Port Aransas (Texas) Rod and Reel Club (PARR); and the Woods Hole Oceanographic Institution (WHOI), Massachusetts.

METHODS AND MATERIALS

The RSMAS program began in 1950 and continued through 1958. During that time tagging kits were distributed to 353 charter and private boat owners; 5,500 tags were distributed. Many of the participating anglers were members of fishing clubs or fishing guide associations who took responsibility of local tag distribution in their area. Of the 35 anglers receiving tagging equipment, 83 tagged 1,262 sailfish. Of these 83 anglers, 25 tagged 83.8% of the total, or 1,058 fish. The tagged fish were released in various areas off southeast Florida from Fort Pierce to Lower Matecumbe Key.

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Four different tag designs were tried during the course of the program. These were:

1. A monel metal "disc tag" fastened to the fish's bill by two strands of silver wire.
2. A neoprene rubber ring with metal strip attached that was applied over the fish's bill.
3. Clamp-on monel and stainless steel tags used to mark the ears of cattle (cattle tags), which were applied to the leading edge of the dorsal or pectoral fin.
4. The Woods Hole Oceanographic Institution "Type B" (Fig. 1) dart tag inserted in the fish's back muscles.

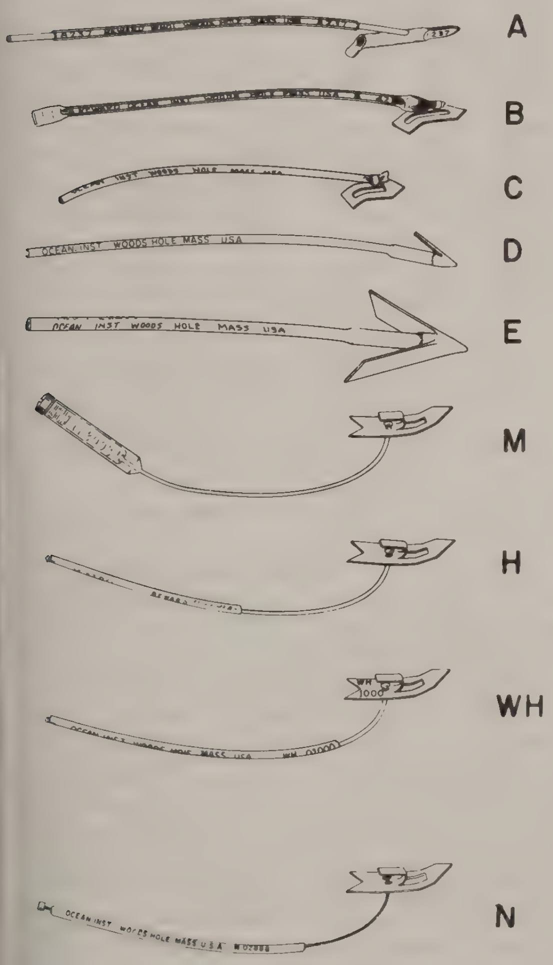

A
B
C
D
OCEAN INST WOODS HOLE MASS USA
E
OCEAN INST WOODS HOLE MASS USA
M
H
WH
N

Figure 1.—Types of tags used for sailfish in the Cooperative Game Fish Tagging Program of WHOI. The type B tag was also one of those used in the Cooperative Sailfish Tagging Program of RSMAS.

PARR members marked 395 sailfish with monel cattle tags (similar to number 3 in the list of tags used by RSMAS), supplied by the club, in the years 1954-1962. The members of PARR began cooperating actively with the WHOI program, using WHOI tags, in 1957, and gradually phased out the use of PARR monel ear tags. The tagging was carried out in the immediate vicinity of Port Aransas.

Sportsmen cooperating with WHOI have tagged over 12,000 sailfish since 1954 with various types of dart tags (Mather, 1963) (Fig. 1). The majority of the tagging was concentrated along the southeast coast of Florida and the Florida Keys, but important numbers of fish were also tagged in the Gulf of Mexico, off the Bahamas, off the Virgin Islands, off Venezuela, and off the Yucatan Peninsula. Lesser numbers were tagged off northeastern Florida, North Carolina, Maryland, and Delaware.

RESULTS

From March 1950 through 15 July 1972, 14,299 sailfish have been tagged and released; 109 returns have resulted. The releases and returns are summarized by year, area of release, and program in Table 1. The release and recapture data for the returns, grouped according to release area and, for the southeast Florida area which comprises most of the returns, by recapture area also, are listed in the Appendix. The monthly distribution of tagging effort in each release area is shown in Table 2. The times at liberty for the recaptured sailfish are summarized in Table 3. The fishing methods by which they were recaptured, and the nationalities of the recapturing vessels, are shown in Table 4.

Tag Returns

The majority (9,710) of the releases were off the southeastern coast of Florida and the Florida Keys (between Fort Pierce and Key West). The majority (80) of the returns were from these releases (Table 1). Most of these recaptures (73) were in this same area, but two were near Havana, three in the Gulf of Mexico, one off North Carolina, and one off the Bahamas (Fig. 2; Appendix Table 1). Among the returns from the release area, the net distance traveled was undeterminable for four and less than 20 miles for 21 (Appendix Table 2), more than 20 miles northward from the release site for 16 (Appendix Table 3), and more than 20 miles southward from the release site for 32 (Appendix Table 4).

Table 1.—Releases (after slash) and returns (before slash) for sailfish, by years, areas, and programs. Returns are listed by year and area of release.

						Gulf of Mexico						
Area	Hatteras-Delaware	NE Florida	SE Florida		Bahamas	Fla. & La.	Texas		Haiti & Virgin Is.[1]	Caribbean SE	Caribbean NW	
Program	WHOI	WHOI	WHOI	RSMAS	WHOI	WHOI	WHOI	PARR	WHOI	WHOI	WHOI	Totals
Year												
1950				1/78								1/78
1951				1/112								1/112
1952				2/102								2/102
1953				1/140								1/140
1954			0/27	0/299				0/76				0/402
1955			1/15	0/201		0/1		1/44				2/261
1956				1/167				0/34				1/201
1957			0/17	2/142			0/7	0/13				2/179
1958			2/7	0/17			0/21	0/36				2/81
1959			0/72			0/1	0/33	1/49		0/7		1/162
1960	0/2		5/746		0/4	0/3	0/22	0/196	0/5	0/44	0/1	5/1,023
1961	0/1	0/1	5/949		0/9	0/5	0/182	1/64	1/3	0/7		7/1,221
1962	0/2	0/4	10/1,141		0/32	0/3	0/93	0/3	0/9			10/1,287
1963	0/4		9/1,000		0/45	0/1	0/102				0/10	9/1,162
1964	0/2		6/925		0/73	0/9	0/60		0/5		0/6	6/1,080
1965	0/1	0/3	7/928		1/34		0/95		1/17	0/15		9/1,093
1966	0/2	0/1	9/565		0/57	0/4	0/152		1/150	7/186	0/22	17/1,139
1967	0/1	1/2	6/385		1/34	2/52	0/188		3/67	0/53	0/46	13/828
1968			6/420		2/43	1/220	1/54		0/20	0/3	0/15	10/775
1969	1/15		3/339		0/71	1/24	0/154		0/53	0/60	0/47	5/763
1970	0/28	0/2	1/254		0/38	0/71	0/73		0/47	0/32	0/76	1/621
1971	0/22	0/2	1/449		0/39	0/35	0/76		0/75	0/31	1/351	2/1,080
1972[2]			0/212		0/29		0/2		1/95	0/1	0/169	1/508
Unknown				1/1								1/1
Totals	1/80	1/15	71/8,451	9/1,259	4/508	4/429	1/1,314	3/515	7/546	7/439	1/743	109/14,299

[1] Haiti-1960-1962, Virgin Islands 1964-1967.

[2] Through May.

The releases in this area were mainly (64.7%) in the period November-February, with a secondary period (14.1%) in April-May. The returns within the release area followed a similar pattern, with majority (44) in the period November-February, but March was the most productive among the other months, with seven returns (Appendix Tables 2-4). The recapture off North Carolina was in July; the one off the Bahamas in December; the two off Havana in May and August; and the three in the Gulf of Mexico also in May (one) and August (two) (Appendix Table 1).

Five hundred and eight sailfish were tagged off the northwestern Bahamas, and four of these tags have been returned (Table 1, Fig. 2, Appendix Table 5). One of these was recaptured off the Florida Keys, one off Cabo Cruz on the southeastern coast of Cuba, two off Havana. Unfortunately there is some doubt about the identity of the last two fish, since the fisherman who recaptured them reported that they were sailfish, but the taggers had listed them as white marlin.

The releases off the northwestern Bahamas are concentrated in April-July (80%) with a good number (8%) in August (Table 2). The two recaptures off Havana were in May and July, the one off southeastern Cuba in March, and the one in the Florida Keys in May (Appendix Table 5).

Fishermen have released 2,358 sailfish in the Gulf of Mexico (1,829 near Port Aransas, Texas, and 429 in the north central and northeastern Gulf) and eight returns have resulted, including four from each area (Table 1, Fig. 2, Appendix Table 6). Two of the recaptures (one in each area) were local. The other three returns from sailfish tagged off Port Aransas showed migrations to the Florida Keys, the vicinity of Palm Beach, Florida, and off the north central coast of Cuba. The remaining three sailfish tagged in the northeastern Gulf were recaptured near Havana, off the northeast coast of Cuba, and west of Grenada in the Lesser Antilles.

The releases off Texas were virtually all in summer, with the majority in July (34%) and August (33%). Those off the Mississippi delta and western Florida were somewhat later, with the maximum in September (49%) and October (34%), and a good number in August (10%) (Table 2). The local recoveries corresponded with the peak of tagging, occurring in August off Port Aransas and in September off Pensacola, Florida. The distant recoveries were scattered in time and location—off Havana in October, near Palm Beach in December, off northeastern Cuba and off Grenada in January, off the Florida Keys in March, and off north central Cuba in May (Appendix Table 6).

Five hundred and twenty-nine sailfish have been tagged off the Virgin Islands, mostly in the period November-March, and six of these tags have been returned (Tables 1 and 2, Appendix Table 7). Two of the returns were local, and in the peak tagging season (December and February). The other recaptures were widely scattered geographically (Fig. 2), but all occurred between mid-March and the end of June. One was in the Mona Passage (off the Dominican Republic) in March, one off Fort Lauderdale, Florida, in May, and the other two were in June—one off the northeastern tip of the Yucatan Peninsula, and the other off Charleston, South Carolina.

Table 2.—Monthly distribution of releases of sailfish in the western North Atlantic Ocean, by tagging areas. Releases are tabulated in percent of the total number (*N*) for each area. — indicates less than 0.5%.

Area	Percent of Releases, by Months												
	Ja	Fe	Ma	Ap	My	Ju	Jl	Au	Se	Oc	No	De	*N*
Southeastern Florida	24	10	3	8	6	4	3	3	3	5	10	21	9,455
Northwestern Bahamas	—	2	4	22	26	18	14	8	2	3	1	—	479
Northwestern Gulf of Mexico					—	6	34	33	25	2			1,827
North Central & Northeastern Gulf of Mexico						2	5	10	49	34	—		429
Virgin Islands	31	14	14	1					1	6	19	13	433
Southeastern Caribbean		8		—	1	5	9	27	18	21	10	—	438
Northwestern Caribbean				22	46	16	10	3			2	1	574
Haiti		6	5		6					17	44	22	18
Northeastern Florida & Georgia						27	60		13				15
Cape Hatteras —Delaware					1	7	41	33	16	2			80

Table 3.—Releases for sailfish in the western North Atlantic Ocean by years, and returns from these by months at liberty.

Releases		Months at Liberty									
Year	Number	0-.9	1-1.9	2-5.9	6-11.9	12-17.9	18-23.9	24-35.9	36-47.9	48-59.9	Total
1950	78					1					1
1951	112		1								1
1952	102			2							2
1953	140							1			1
1954	402										
1955	261				1		1				2
1956	201							1			1
1957	179	1				1					2
1958	81				1	1					2
1959	162						1				1
1960	1,023		2	1	1	1					5
1961	1,221	1		2	2	2					7
1962	1,287	2	1	1	5	1					10
1963	1,162	3	1	4	1						9
1964	1,080	2	2	1	1						6
1965	1,093	2	1	2	3	1					9
1966	1,139	5		4	4		2	1		1	17
1967	828	2	2	7	1	1					13
1968	775	3	1	1	3	1	1				10
1969	763	1	1	2		1					5
1970	621	1									1
1971	1,080				2						2
1972	508			1							1
Unknown	1										1
All Years	14,299	23	12	28	25	11	5	3		1	109

Fishermen have released 438 sailfish in the southeastern Caribbean, nearly all of them in the vicinity of La Guaira, Venezuela (Fig. 2), and seven of these tags have been returned (Table 1, Appendix Table 8). Most of the tagging (66%) was in the period July-October, with 8 to 10% in each of the months of July, November, and February (Table 2). Six of the recaptured fish had been tagged near La Guaira; the other was released about 60 miles west of there. All were recaptured in the vicinity of La Guaira. The recaptures were spread over much of the year, with one in each of the months of January, May, June, July, and August, and two in September.

Five hundred and seventy-four sailfish have been tagged in the northwestern Caribbean, nearly all of them along the Yucatan coast opposite Cozumel

Island, Mexico, but only one of these tags has been returned (Table 1, Appendix Table 9). The tagging was concentrated in April-June (84%), with 10% in August (Table 2). The single recapture was near the easternmost end of the Caribbean coast of Venezuela in December (Fig. 2).

Eighty sailfish have been tagged off the U.S. coast from Cape Hatteras to Delaware Bay, nearly all in summer, and one of these has been recaptured (Tables 1 and 2, Appendix Table 9). This tag was recovered in March off the Guianas (Fig. 2), about 1,920 miles (3,070 km) from the release point, representing the longest migration yet recorded for a sailfish.

One return was obtained from only 15 releases off northeastern Florida and Georgia, most of them in the vicinity of Jacksonville, Florida, in June and July (Tables 1 and 2, Appendix Table 9). This fish was recaptured off Fort Lauderdale, Florida, in October (Fig. 2).

Another small group of releases, 18, off Haiti likewise produced a single return (Table 1, Appendix Table 3). Most of the releases were in October-December (Table 2), but the recaptured fish was tagged in May. It was recaptured in the release area, off Port-au-Prince, in January (Fig. 2).

The times at liberty which are available for tagged and recaptured sailfish are summarized in Table 3. Although the maximum was over 4.5 years, the majority of the times at liberty were of very short duration. Fifty-eight percent were less than 6 mo, and 90% were less than 18 mo.

The methods of recapture, and the nationality of recapturing vessels, are shown in Table 4. Eighty-two percent of the known recaptures were by sport fishermen, nearly all of whom were from the United States. Eighteen percent were by commercial fishermen using various types of hook-and-line gear. Most of these were by Cuban fishermen (nine returns) and Venezuelan fishermen (seven returns). Japanese longline vessels produced only one valid return, but also returned a dart found in a sailfish recaptured in the Gulf of Mexico in August 1971. Since the streamer, which carried the serial number, had been lost, the release data were unavailable.

DISCUSSION

Migrations

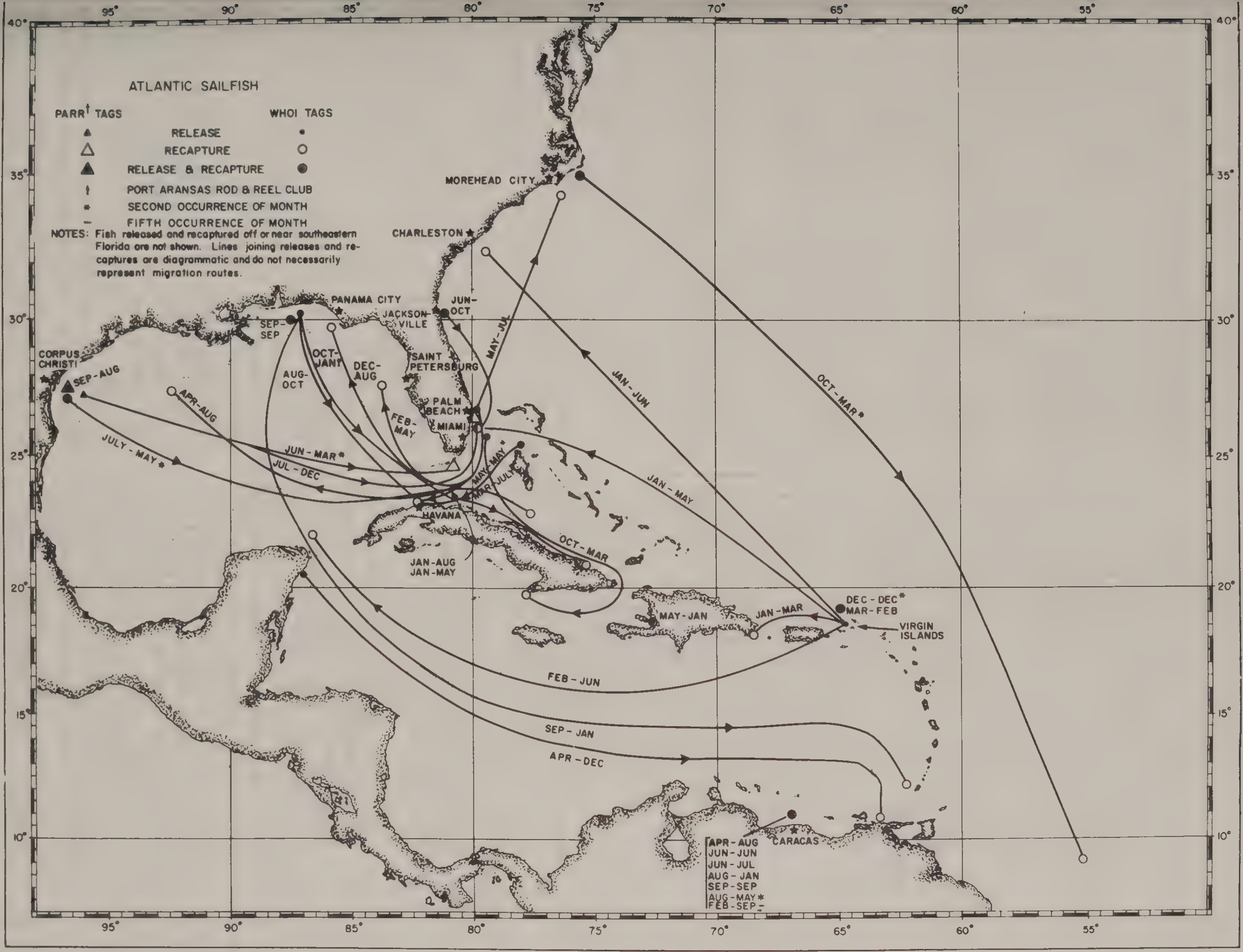
Although tag returns have produced much information on migrations (Fig. 2) and local movements of sailfish, it is difficult to detect regular patterns on a geographical basis. If one considers water temperatures, however, some general tendencies become discernible. Eight sailfish tagged in temperate areas (six in the northern Gulf of Mexico, one off Jacksonville, and one off Cape Hatteras) mainly during the warm season (releases between 8 June and 18 October) were recaptured in tropical waters (three off the north coast of Cuba, three off southeastern Florida and the Florida Keys, and two near the northeastern coasts of South America) mainly in the cool season (recaptures between 10 October and 20 May) (Appendix Tables 6, 9). Five sailfish tagged in tropical areas (four near Palm Beach, Florida, and one off the Virgin Islands) mainly during the cool season (releases between 8 December and 10 May) were recaptured in temperate areas (three in the Gulf of Mexico and two off the Carolinas) mainly during the warm season (recaptures from 22 May through 2 August) (Appendix Tables 1,7).

Some movements within tropical waters may have been parts of similar migrations. Three sailfish tagged off the Virgin Islands in January and February were recaptured as follows: in the Mona Passage (off the Dominican Republic) in March (2.1 mo at liberty); in the Yucatan Channel (northeast of

Table 4.—Tag returns from sailfish released in the western North Atlantic Ocean, by methods of recapture and nationality of recapturing vessel.

	Sport	
Bahamas	Rod and Reel	1
United States	Rod and Reel	86
Venezuela	Rod and Reel	2
Sport total		89
	Commercial	
British West Indies	Handline	1
Cuba	Longline	4
	"Criollo" line	5
Dominican Republic	Handline	1
Haiti	Deepline	1
Japan	Longline	1
Venezuela	"Professional Fishermen"	6
	Longline	1
Commercial total		20
	All Methods	
Grand total		109

Figure 2.—Longer migrations shown by returns from sailfish tagged in the western North Atlantic Ocean. Migrations entirely within the Straits of Florida are not shown


ATLANTIC SAILFISH
PARR† TAGS
WHOI TAGS
▲ RELEASE •
△ RECAPTURE ○
▲ RELEASE & RECAPTURE ●
† PORT ARANSAS ROD & REEL CLUB
* SECOND OCCURRENCE OF MONTH
– FIFTH OCCURRENCE OF MONTH
NOTES: Fish released and recaptured off or near southeastern Florida are not shown. Lines joining releases and recaptures are diagrammatic and do not necessarily represent migration routes.
MOREHEAD CITY
CHARLESTON
PANAMA CITY
JACKSON-VILLE
JUN-OCT
SEP-SEP
CORPUS CHRISTI
SEP-AUG
OCT-JAN
DEC-AUG
AUG-OCT
SAINT PETERSBURG
PALM BEACH
MIAMI
FEB-MAY
APR-AUG
JULY-MAY*
JUN-MAR*
JUL-DEC
MAY-JUL
MAY-MAY*
MAR-JULY
HAVANA
JAN-AUG
JAN-MAY
JAN-JUN
OCT-MAR*
JAN-MAY
OCT-MAR
MAY-JAN
JAN-MAR
DEC-DEC*
MAR-FEB
VIRGIN ISLANDS
FEB-JUN
SEP-JAN
APR-DEC
CARACAS
APR-AUG
JUN-JUN
JUN-JUL
AUG-JAN
SEP-SEP
AUG-MAY*
FEB-SEP–
95°
90°
85°
80°
75°
70°
65°
60°
55°
40°
35°
30°
25°
20°
15°
10°

the Yucatan Peninsula) in June (4.1 mo at liberty); and off Fort Lauderdale, Florida, in May (4.0 mo at liberty) (Appendix Table 7). The first two fish might have been on their way to the northern Gulf of Mexico, or, as the third could also have been, to the Jacksonville-Cape Hatteras area. A sailfish released off Palm Beach in January and recaptured off Havana in May (3.3 mo at liberty) (Appendix Table 1) might well have been en route to the northern Gulf of Mexico.

Thus the majority (eight) of the 13 recorded sailfish migrations between temperate and tropical waters were between the northern Gulf of Mexico in the warmer season and the waters off southeastern Florida and the north coast of Cuba in the cooler season. Similar migrations have been recorded for tagged white and blue marlins (Mather, Jones, and Beardsley, 1972; Mather, Mason, and Clark, 1974), although several of these originated off the northwestern Bahamas. There seems to be a strong tendency for sailfish, as well as other billfishes, to spend the warm-water season in the northern Gulf of Mexico, and the season when the waters there are cool, in the Straits of Florida and adjacent waters. Gibbs (1957) showed the white marlin distribution in the Gulf of Mexico was closely related to the seasonal movements of the 75°F (23.9°C) isotherm. Since the range of the sailfish does not extend into waters as cool as that of the white marlin (Ueyanagi et al., 1970) it seems probable that the position of the 25°C isotherm might control their distribution.

Similar, but less frequent, seasonal changes of habitat by tagged sailfish have been between the Straits of Florida and the Virgin Islands in the cool season and the Jacksonville-Cape Hatteras area in the warm season (two northward migrations and one southward); and between the latter area and the Gulf of Mexico in the warm season, and waters near northeastern South America in the cool season (two southward migrations) (Fig. 2, Appendix Tables 1, 6, 7, 9). Like the more numerous seasonal migrations between the Gulf of Mexico and the Straits of Florida area, these migrations may be related to the seasonal temperature changes in the summering areas. The data are insufficient to determine whether different stocks occupy the two summering areas (Gulf of Mexico, Jacksonville-Cape Hatteras) or not. It seems highly probable, however, that fish from these two summer habitats mingle with each other in three wintering areas —Straits of Florida, Virgin Islands, and off South America. Since the recovery of tags is probable in only a few relatively small areas of intensive fishing, the picture obtained from tag returns may be misleading. It is quite likely that the seasonal habitats of sailfish are considerably larger than is indicated here. Possibly the wintering area is continuous from the Straits of Florida and the northwestern Bahamas to northeastern South America.

In contrast to the long migrations recorded from other areas where numerous sailfish have been tagged, all seven returns from the 439 releases off Venezuela have been local even though times at liberty have ranged up to 54.8 mo (Table 2, Appendix Table 8). This is a strong indication that most of the sailfish there are of a local stock, or one which does not enter other areas of intensive fishing. Tag returns (Fig. 2) suggest, however, that sailfish from the northern Gulf of Mexico, the Jacksonville-Cape Hatteras area, and off the northeastern coast of the Yucatan Peninsula may mingle with those off Venezuela.

The extremely low return rates for sailfish tagged off Yucatan and in the northwestern Gulf of Mexico (Table 2) suggest that these fish may also be of stocks which do not often enter other areas of intensive fishing.

It is also surprising that, with 9,710 sailfish tagged off southeastern Florida and 508 tagged off the northwestern Bahamas, only two migrations (one in each direction) between these areas have been recorded (Appendix Tables 1, 5). This small amount of mixing again raises the possibility of separate stocks.

In view of the present low rate of return from sailfish tagging, it seems especially important to conduct genetic studies of sailfish in the respective areas to identify the stocks or populations. Perhaps the tagging results could assist in the selection of sampling periods and areas when mixing of fish from different areas is least probable.

The numerous local movement records within the Fort Pierce-Key West area (southeastern Florida) are very difficult to analyze (Appendix Tables 2, 3, 4). More southward (32) than northward (16) migrations were recorded, but this may only reflect the fact that the majority of the tagging occurred in the northernmost part of this area (Palm Beach Fort Pierce). Fishing effort from Palm Beach southward to Key West is intense, whereas it i relatively light north of Fort Pierce. Most of th tagged sailfish which migrated northward in th area were released in October-April and recapture in December-February; most of those which migrated southward were released in November-February and recaptured in November-March. Most of those recaptured within 20 miles (32 km) of the release point were released in November-anuary and June, and recaptured in November-December and February-April. The longer northward migrations (Key West-Marathon to Palm Beach-Stuart) were by four fish, released in March, April, October, and November and recaptured in December, January, May, and July. The longest southward migrations (Palm Beach-Stuart to Key West-Islamorada) were by four fish, released in anuary, March, and April, and recaptured in anuary, February, March, and July. There seems o be little consistency in these data.

Two rather rapid southward migrations along the Florida coast have been recorded; from off Jupiter o off Fort Lauderdale in 2 days, and from off Hillsboro Inlet to off Miami in the same period. It might be of interest to check such migrations gainst historical weather data. Fishermen in the rea often observe sailfish riding the downwind face of waves with the upper lobe of their caudal fin howing ("tailing"), particularly during the brisk northerly winds which herald cold weather.

Growth and Survival

Since sizes at release are estimated, and the quality of recapture data is difficult to evaluate, especially in regard to length measurements, no valid growth data are available. In the WHOI program instructions, the cooperating taggers are asked to measure the length of the head of each billfish tagged, which would permit a close estimate of the body length of the fish. No taggers have done this. esides the extra time and trouble involved, this procedure might well increase the risk of injury to both fish and tagger. Several sailfish were recaptured after from 1 to 4 yr at liberty. These do not ppear to have been especially small when tagged, r especially large when recaptured. This may be an dication that the species does not grow very fast after reaching the age of recruitment to the fishery.

Eighty-eight of the 108 recaptured sailfish for hich time at liberty was known, at least approximately, were recaptured less than a year after being agged. Only 11 more had been at liberty for 12-18 mo, and an additional five for 18-24 mo. Thus only four were recaptured after from 2 to 5 yr at liberty. hese results are in good agreement with de Sylva's (1957) work, which indicated that the life span of the species was short.

The question of the survival of released fish remains unanswered. The low return rate for tagged sailfish could be an indication of high tagging mortality. Return rates also depend on the percent of the stock which is caught, as well as on natural mortality, tag shedding, and other factors. Return rates for white marlin and small bluefin tuna were even lower than those for sailfish in the years 1954-1961, but, with the increased fishing effort for these species, the rates for white marlin have risen appreciably, and those for small bluefin have become alarming (FAO, 1968; Mather, Jones, and Beardsley, 1972; Mather et al., 1974). Only two rather small and localized commercial fisheries have returned significant numbers of sailfish tags; over 80% of the tags have been returned by sport fishermen. In the absence of an effective commercial fishery, a high return rate from such a short-lived and widely ranging species can hardly be expected. Experiments to study the survival of tagged fish, possibly through the use of acoustic tags, are needed to settle this important question.

Comparison of Tag Types

Data from the early years provide indications of the practicality and effectiveness of the various types of tags. In the RSMAS program, the disc tag was soon discarded because of the difficulty encountered by the fishermen in twisting the wires to assure a snug fit on the bill without keeping the fish out of water too long. The neoprene rubber ring was discarded after a single recapture showed that the pressure of the rubber on the bill was actually severing the bill. The cattle tags were popular with the anglers; they could be applied quickly. However, they were often knocked from the special pliers by the struggling fish and the pliers used to apply them were expensive. The "Type B" Woods Hole dart tag was the most popular with anglers since the fish could be tagged without handling them (Mather, 1963).

On the basis of recoveries, the cattle tag and the Woods Hole Type B dart tag were about equally effective. There is reason to believe that some tags may have been overlooked by anglers since some of those that were recovered had goose barnacles and algae attached to them and could not be recognized easily.

In the tagging off Port Aransas, however, the cattle ear tags used in the PARR program produced a much higher return rate (0.7%) than the dart tags used in the WHOI program (0.1%).

The results with the various types of dart tags used in the WHOI program (Fig. 1) have not been completely analyzed. Experience has shown, however, that the dart tags with plastic heads (types D and E) are not as practical for tagging under the conditions of this program. The applicators are mounted on the end of a pole 1.0-1.5 m long, and the fish are tagged without removing them from the water, and preferably without handling them (Mather, 1963). Under these circumstances, the plastic heads of the type D and E darts are frequently broken. The broken tags often jam in the tubular applicators which are used for these tags, and the applicators themselves are easily damaged and difficult to repair or replace. The tags with stainless steel darts (types A, B, C, H, M, N and WH), which are used with slotted, solid stainless steel applicators, are much more rugged and trouble free, and do not jam in the applicators. The applicators themselves are also more rugged than the tubular ones, and are much more easily repaired or replaced when damaged. There has been no evidence that the stainless steel dart is more injurious to the fish than the plastic one, as was feared.

There was some evidence that the streamers sometimes separated from both types of darts, because of glue failure, defective assembly, or insufficient basic mechanical strength. The WH tag, with the serial number on the dart as well as the streamer, was developed with financial assistance from P.A.B. Widener in hopes that valid returns could be obtained even if the streamer had been lost. Perhaps due to insufficient publicity, or perhaps because this separation did not occur as often as was supposed, these tags have not produced any significant increase in return rates. Recent improvements in the construction of type H, N, and WH tags, however, have so increased their uniformity and mechanical strength that we do not believe that tag separation will be a significant factor.

SUMMARY

1. The data suggest seasonal migrations between summering areas in temperate waters (Gulf of Mexico, U.S. coast from northern Florida to North Carolina) and wintering areas in tropical waters (Straits of Florida, West Indies, north coast of South America). These migrations may be related to the location of the 25°C isotherm.

2. The extremely localized nature of the intensive southeast Florida sport fishery makes the local movements within that area difficult to interpret. More tagging in other areas might produce more significant results.

3. There are some indications of separate stocks, but, if they are indeed separate, many of them probably mingle with others.

4. No reliable growth data were obtained. The results suggest, however, that the growth rate of sailfish decreases rather rapidly with increasing size of fish.

5. Times at liberty for recaptured sailfish ranged up to 5 yr, but 95% were less than 1 yr. These results indicate that the life span of the species is short.

6. Over 80% of the returned tags were recaptured by the sport fishery. This indicates that commercial fishing pressure on the stocks under study is slight.

7. Tag return rates of less than 1% do not suggest a high survival rate for released sailfish.

8. This low return rate may be caused by low fishing mortality and the short life span of the species. Direct studies of the survival of released fish are required.

9. The cattle ear tag and the dart tag proved to be the most practical of the types which were used for tagging sailfish. The former produced higher return rates than the latter, but the dart tag equipment is less costly and easier to use. The dart tags with metal heads were generally more satisfactory than the ones with plastic heads.

ACKNOWLEDGMENTS

The authors are most grateful to all the organizations and individuals who have assisted this research. Funding for the RSMAS program was provided by the Florida State Board of Conservation. The principal financial support of the WHOI program since 1956 has been from the National Science Foundation (Grants G-861, G-2102, G-8339, G-6172, G-19601, GB-3464 and GH-82), the Bureau of Commercial Fisheries (now National Marine Fisheries Service) (Contracts 14-17-0007-272, -547, -870, -975, and -1110) and the Office of Sea Grant, National Oceanic an Atmospheric Administration, U.S. Department o Commerce (Grant GH-82). Important additiona support has been received from the Sport Fishin

nstitute; the Charles W. Brown, Jr. Memorial
oundation; the Tournament of Champions
through Mrs. R.C. Kunkel and E.D. Martin); A.
Minis, Jr.; the Joseph A. Teti, Jr. Foundation; the
Port Aransas Rod and Reel Club; P.A.B. Widener;
he Jersey Cape Fishing Tournament; the As-
ociates of the Woods Hole Oceanographic Institu-
ion; and many other sportsmen's organizations and
ndividual sportsmen.

The National Marine Fisheries Service and its
predecessor, the Bureau of Commercial Fisheries,
he Inter-American Tropical Tuna Commission,
he Fisheries Research Board of Canada, the Food
and Agriculture Organization of the United Na-
ions, and many other national and private research
organizations have assisted in the promoting of the
agging of fishes, the collection and processing of
data, and the dissemination of information on the
program and its results. The contributions of
Donald P. de Sylva and Gilbert L. Voss are espe-
cially appreciated.

The tagging results were made possible by the
housands of anglers, captains, and mates who have
agged, and released many of their catches, and the
clubs, committees and individuals who have en-
couraged tagging. We regret that space does not
permit individual acknowledgements here; the
major participants are listed in the informal pro-
gress reports which are issued periodically by
WHOI. Most of the participants in the RSMAS and
PARR programs have also participated in the
WHOI program. The press and the broadcasting
media have also done much to encourage tagging
and the return of tags.

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APPENDIX

Release and recapture data for returns from sailfish tagged in the western North Atlantic Ocean, March 1950-May, 1972, are given in nine Appendix Tables. The returns are grouped by area of release, except that the large group from releases of southeastern Florida is further divided according to recapture areas. In each group, the returns are listed in order of date of recapture. Lengths and weights which were reported in inches and pounds have been converted to centimeters and kilograms. Data in parentheses are extimated or approximate.

APPENDIX TABLE 1: Sailfish tagged off southeast Florida and the Florida Keys and recaptured in other areas.

Release data					Recapture data							
Date	Locality		Estimated size		Date	Locality		Size		Gear[1]	Flag	Months at Liberty
	Lat N	Long W	Length	Weight		Lat N	Long W	Length	Weight			
			cm	*kg*				*cm*	*kg*			
Feb. 10, 1960	(26°45'	79°55')	(210)		May 22, 1960	27°40'	83°45'	(180)		RR	USA	3.4
May 10, 1963	(26°45'	79°55')	(220)		July 25, 1963	34°19'	76°17'	201		RR	USA	2.5
Apr. 13, 1964	(26°32'	80°00')	(210)	(18.2)	Aug. 2, 1964	27°28'	92°27'			LL	Jap.	3.6
Nov. 20, 1964	(27°04'	80°03')	(220)	(19.1)	Dec. 4, 1964	26°54'	79°07'			RR	Bah.	0.5
Jan. 28, 1966	(26°45'	79°55')			May 8, 1966	23°10'	82°25'	192	18.2	LL	Cuba	3.3
Jan. 19, 1966	(26°56'	80°00')	(200)		Aug. 5, 1966	(23°10'	82°25')		14.1	LL	Cuba	6.6
Dec. 8, 1966	(26°45'	79°55')		(9.1)	Aug. 1, 1967	29°55'	85°52'	203		RR	USA	7.8

[1] RR, rod and reel; LL, longline

APPENDIX TABLE 2: Sailfish tagged off southeast Florida and the Florida Keys and recaptured less than 20 miles or an undeterminable distance from the release site.

Release data					Recapture data							
Date	Locality		Estimated size		Date	Locality		Size		Gear[1]	Flag	Months at Liberty
	Lat N	Long W	Length	Weight		Lat N	Long W	Length	Weight			
			cm	kg				cm	kg			
*Oct. 1, 1957	(26°32'	80°00')			Oct. 1, 1957	(26°32'	80°00')			RR	USA	0.0
*Unknown					Nov. 5, 1957	(26°15'	80°00')			RR	USA	
Feb. 6, 1960	(27°04'	80°00')	(200)		Jan. 18, 1961	(27°10'	80°00')	(230)	(21.6)	RR	USA	11.4
Dec. 23, 1960	(26°45'	79°55')	(190)		Jan. 23, 1961	(26°45'	79°55')	214	20.4	RR	USA	1.0
Apr. 3, 1962	(26°32'	80°00')	(150)	(9.1)	Sept. 8, 1962	(26°15'	80°00')	188	12.5	RR	USA	5.2
Mar. 1963	(26°32'	80°00')			Mar. 1963	(26°32'	80°00')	221		RR	USA	
Mar. 1963	(26°15'	80°00')			June 1963	(26°32'	80°00')			RR	USA	3.
Nov. 1963	(26°13'	80°03')	(210)		Nov. 28, 1963	(26°05'	80°05')	216	21.8	RR	USA	12.
Sept. 27, 1963	(26°20'	80°02')		(18.2)	June 30, 1964	(26°05'	80°05')	211	14.5	RR	USA	9.3
Dec. 28, 1964	(26°56'	80°00')	228		Dec. 28, 1964	26°57'	80°02'			RR	USA	0.0
Dec. 10, 1965	(26°45'	80°00')	(200)		Dec. 11, 1965	26°45'	79°58'	211	27.2	RR	USA	
Nov. 27, 1965	(26°54'	80°00')	(220)	(21.8)	Dec. 22, 1965	(26°32'	80°00')	224	22.8	RR	USA	0.8
Nov. 30, 1965	(26°15'	80°00')	(210)		Jan. 17, 1966	(26°31'	80°00')	214	24.6	RR	USA	1.6
Dec. 1, 1965	(26°45'	79°55')	(210)	(18.2)	Nov. 13, 1966	(26°32'	80°00')	202	17.7	RR	USA	11.4
Dec. 12, 1965	(26°32'	80°00')	(190)	(13.6)	Nov. 14, 1966	(26°20'	80°02')	173	9.1	RR	USA	11.0
Dec. 28, 1966	(26°56'	80°00')		(18.2)	Jan. 2, 1967	(27°10'	80°00')	214	(21.6)	RR	USA	0.2
Apr. 29, 1967	(26°05'	80°05')		(27.2)	June 5, 1967	25°45'	80°06'		27.2	RR	USA	1:2
Jan. 17, 1967	27°01'	80°02'			Unknown					RR	USA	
Feb. 11, 1967	(26°45'	79°55')			Unknown			(210)	(17)	RR	USA	
Jan. 2, 1967	(27°03'	80°04')			Unknown			(210)	(17)	RR	USA	
Feb. 4, 1966	(26°21'	80°03')	(200)		Dec. 7, 1967	(26°21'	80°03')	208		RR	USA	22.1
Unknown	(26°45'	79°55')			Feb. 10, 1968	(26°54'	80°00')	214		RR	USA	
Feb. 2, 1968	27°23'	80°02'			Feb. 18, 1968	27°09'	80°03'	201	15.7	RR	USA	0.5
Dec. 8, 1967	(26°21'	80°03')	(200)		Apr. 18, 1968	26°38'	80°00'	218		RR	USA	4.4
Jan. 3, 1968	(26°45'	79°55')		(20.4)	Jan. 3, 1969	(26°35'	80°00')	221	25.4	RR	USA	12.0

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[1] RR, rod and reel

*Fish tagged under program sponsored by the Rosenstiel School of Marine and Atmospheric Science (RSMAS)

APPENDIX TABLE 3: Sailfish tagged off southeast Florida and the Florida Keys and recaptured in the same area more than 20 miles northward from the release site.

Release data					Recapture data							
Date	Locality		Estimated size		Date	Locality		Size		Gear[1]	Flag	Months at Liberty
	Lat N	Long W	Length	Weight		Lat N	Long W	Length	Weight			
			cm	kg				cm	kg			
*Apr. 4, 1952	24°51'	80°36'			July 12, 1952	(25°45'	80°00')			RR	USA	3.3
*July 16, 1957	25°45'	80°06'	(200)		Sept. 15, 1958	27°10'	80°03'	216		RR	USA	14.0
Jan. 28, 1958	(26°45'	79°55')	(220)		Jan. 14, 1959	(27°10'	80°00')	219	18.2	RR	USA	11.5
*Feb. 19, 1956	24°51'	80°36'	(200)	(9.1)	Feb. 12, 1959	(26°28'	80°02')	216	21.8	RR	USA	35.8
Mar. 2, 1961	(26°13'	80°00')	(210)	(18)	Jan. 19, 1962	(27°27'	80°05')	213		RR	USA	10.6
Mar. 16, 1962	(24°38'	81°06')	(170)		Dec. 15, 1962	(26°32'	80°00')	(180)	(12.5)	RR	USA	9.1
Dec. 24, 1962	(26°13'	80°03')	(200)	(13.6)	Feb. 22, 1963	(26°45'	79°55')	206	14.1	RR	USA	2.0
Dec. 6, 1963	(26°45'	79°55')	(190)	(14.5)	Dec. 7, 1963	27°13'	80°03'	185	13.6	RR	USA	
Nov. 27, 1964	(26°13'	80°03')	(200)		Dec. 29, 1964	(26°56'	80°00')	(230)		RR	USA	1.0
Apr. 25, 1966	(24°40'	81°05')		(16)	Jan. 3, 1967	27°12'	80°05'	(224)	(22.8)	RR	USA	8.3
Mar. 12, 1968	25°12'	80°14'			Apr. 29, 1968	25°53'	80°05'			RR	USA	1.6
Jan. 21, 1969	(26°45'	79°55')		(18.2)	Jan. 24, 1969	27°28'	79°59'	(180)	(13.6)	RR	USA	0.1
Nov. 15, 1968	(24°40'	81°05')	(180)	(11.4)	May 18, 1969	(26°45'	79°55')	173		RR	USA	6.0
Oct. 26, 1969	(24°40'	81°05')	(190)	(18.2)	Dec. 1, 1969	(25°45'	80°00')	216	24.6	RR	USA	1.2
Oct. 12, 1969	25°33'	80°05'		(22.8)	Dec. 23, 1969	26°57'	80°03'	224	24.1	RR	USA	2.3
Oct. 25, 1971	(24°30'	81°45')	(210)	(18.2)	July 1972	(26°45'	80°00')	206		RR	USA	8.3

[1] RR, rod and reel

* Fish tagged under the program sponsored by RSMAS

APPENDIX TABLE 4: Sailfish tagged off southeast Florida and the Florida Keys and recaptured in the same area more than 20 miles southward from the release site.

Release data					Recapture data							
Date	Locality		Estimated size		Date	Locality		Size		Gear[1]	Flag	Months at Liberty
	Lat N	Long W	Length	Weight		Lat N	Long W	Length	Weight			
			cm	kg				cm	kg			
*Jan. 28, 1951	(27°10'	80°00')			Mar. 15, 1951	(26°45'	79°55')			RR	USA	1.8
*Dec. 26, 1950	(27°10'	80°00')	214	18.2	Feb. 21, 1952	(26°32'	80°00')	234	25.4	RR	USA	13.9
*Dec. 23, 1952	(27°10'	80°04')			Mar. 27, 1953	(26°45'	79°55')			RR	USA	3.1
Dec. 1954 or Jan. 1955	(27°10'	80°00')			Jan. 12, 1956	(25°00'	80°30')	206		RR	USA	11.8
*Dec. 30, 1953	(27°10'	80°00')	191	13.6	Feb. 20, 1956	(26°32'	80°00')	221	22.8	RR	USA	25.8
Feb. 5, 1958	(26°45'	79°55')	(210)	(21)	Apr. 19, 1959	(26°15'	80°00')	211	23.4	RR	USA	14.4
Nov. 11, 1960	(26°45'	79°55')	(200)		Jan. 7, 1961	(26°05'	80°05')	198	15.5	RR	USA	1.9
Feb. 5, 1961	(27°04'	80°00')	(200)		Feb. 26, 1961	(26°32'	80°00')			RR	USA	0.7
Jan. 28, 1960	(27°04'	80°00')			Mar. 8, 1961	(25°00'	80°30')	216	(20.4)	RR	USA	13.2
Feb. 4, 1961	(26°45'	79°55')	(220)		May 11, 1961	(25°45'	80°00')	224	20.6	RR	USA	3.2
Jan 29, 1961	(26°56'	80°00')	(210)		Jan. 31, 1962	(26°05'	80°05')	155	(15.9)	RR	USA	0.1
Dec. 15, 1962	(26°15'	80°00')	(230)		Dec.29, 1962	(25°45'	80°00')	218	23.8	RR	USA	0.5
Jan. 20, 1962	(27°27'	80°05')	198	15.9	Jan. 9, 1963	(26°45'	79°55')	206	(13.6)	RR	USA	11.8
Dec. 31, 1961	(26°56'	80°00')	198	(11.4)	Jan. 9, 1963	(26°28'	80°02')	198	15	RR	USA	12.3
Jan. 3, 1963	(26°56'	80°00')	(210)		Feb. 22, 1963	(26°15'	80°00')	203	24.3	RR	USA	1.6
Apr. 14, 1962	(26°32'	80°00')			Feb. 25, 1963	(25°45'	80°00')		23.2	RR	USA	10.4
Jan. 31, 1962	(26°56'	80°00')	(220)		Mar. 9, 1963	(26°15'	80°00')	211	17.7	RR	USA	13.2
Jan. 5, 1963	(26°45'	79°55')	(230)		Mar. 14, 1963	(25°45'	80°00')	218	23.6	RR	USA	2.2
May 11, 1963	(26°20'	80°02')	(120)	(9.1)	May 12, 1963	25°45'	80°07'	175	11.8	RR	USA	
Jan. 10, 1963	(26°56'	80°00')	(150)		May 17, 1963	(26°32'	80°00')			RR	USA	4.2
Dec. 26, 1961	(26°45'	79°55')	(200)		June 24, 1963	(25°45'	80°00')	203	15.5	RR	USA	17.8
Oct. 10, 1962	(26°20'	80°02')			Aug. 12, 1963	25°45'	80°07'	206	20.4	RR	USA	10.1
Jan. 4, 1964	(27°10'	80°00')	(220)		Feb. 27, 1964	(26°47'	80°00')			RR	USA	1.8
Apr. 2, 1964	(26°45'	80°00')	(180)		Mar. 17, 1965	24°33'	81°07'	218		RR	USA	11.5
Nov. 14, 1965	Unknown		183	13.6	Apr. 1966	(25°45'	80°00')	188	15.9	RR	USA	5.
Mar. 2, 1966	27°05'	80°05	198		July 12, 1966	24°30'	81°50'	200	14.5	RR	USA	4.3
Nov. 11,1966	(26°54'	80°00')	(210)	(18.2)	Nov. 19, 1966	25°35'	80°06'	203	16.4	RR	USA	0.3
Dec. 19, 1965	(26°45'	79°55')	(180)		Jan. 23, 1967	25°16'	80°10'	180	18.2	RR	USA	13.2
Nov. 22, 1967	(26°15'	80°00')	(210)	(20.4)	Nov. 24, 1967	(25°45'	80°00')	228	23.2	RR	USA	0.1
(Feb. 26, 1966)	(26°45'	79°55')			Nov. 19, 1968	(26°05'	80°05')	226	26.4	RR	USA	(32.8)
Jan. 22, 1968	27°23'	80°02'	(210)	(22.7)	Dec. 29, 1968	25°55'	80°04'	216	21.4	RR	USA	11.2
Nov. 18, 1970	(24°40'	81°05'	91	9.1	Nov. 26, 1970	24°26'	81°52'		6.4	RR	USA	0.3

[1] RR, rod and reel

* Fish tagged under program sponsored by RSMAS

APPENDIX TABLE 5: Sailfish tagged of the northwestern Bahamas.

Release data					Recapture data							
Date	Locality		Estimated size		Date	Locality		Size		Gear[1]	Flag	Months at Liberty
	Lat N	Long W	Length	Weight		Lat N	Long W	Length	Weight			
			cm	kg				cm	kg			
Oct. 21, 1965	25°45'	79°19'	(210)	(18.2)	Mar. 17, 1966	19°45'	77°43'		20.4	LL	Cuba	4.8
May 2, 1967	25°25'	77°55'		(18.9)	May 4, 1968	(23°10'	82°25')	150	20.9	LL	Cuba	12.1
Mar 21, 1968	25°25'	77°55'	(230)		July 20, 1968	23°14'	82°30'		18	LL	Cuba	4.0
Aug. 28, 1968	25°45'	79°19'		(22.8)	May 31, 1969	24°47'	80°32'	213	18.2	RR	USA	9.0

[1] RR, rod and reel; LL, longline; CL, criollo line

APPENDIX TABLE 6: Sailfish tagged in the Gulf of Mexico.

Release data					Recapture data							
Date	Locality		Estimated size		Date	Locality		Size		Gear[1]	Flag	Months at Liberty
	Lat N	Long W	Length	Weight		Lat N	Long W	Length	Weight			
			cm	kg				cm	kg			
*June 8, 1955	(27°35'	96°45')	(210)		Mar. 9, 1957	(25°00'	80°30')			RR	USA	21.0
*Sept. 15, 1959	(27°35'	96°45')			Aug. 14, 1961	(27°35'	96°45')	(220)		RR	USA	23.0
*July 4, 1961	(27°35'	96°45')	(210)		Dec. 22, 1961	(26°32'	80°00')	186	17	RR	USA	5.6
Aug. 3, 1967	30°18'	86°36'	213	(17.3)	Oct. 17, 1967	23°16'	82°08'	198		LL	Cuba	2.5
Oct. 7, 1967	30°07'	86°50'	(210)		(Jan. 1968)	21°03'	75°30'			CL	Cuba	(3.)
Sept. 12, 1968	30°05'	86°52'	(200)		Sept. 23, 1968	30°05'	86°53'	216		RR	USA	0.4
Sept. 30, 1969	30°05'	87°00	228		Jan. 6, 1970	12°08'	61°49'		20.9	HL	BWI	3.2
July 20, 1968	27°30'	96°40'	(200)		May 20, 1970	22°09'	77°40'	(180)		CL	Cuba	22.0

[1] RR, rod and reel; LL, longline; CL, criollo line; HL, handline

* Fish tagged under the program sponsored by the Port Aransas Rod and Reel Club.

APPENDIX TABLE 7: Sailfish tagged off the Virgin Islands

Release data					Recapture data							
Date	Locality		Estimated size		Date	Locality		Size		Gear[1]	Flag	Months at Liberty
	Lat N	Long W	Length	Weight		Lat N	Long W	Length	Weight			
			cm	*kg*				*cm*	*kg*			
Dec. 26, 1965	18°30'	64°45'			Dec. 11, 1966	18°32'	64°40'	216	18.2	RR	USA	11.5
Mar. 11, 1966	18°32'	64°40'	(220)		Feb. 10, 1967	18°32'	64°40'	219	18.2	RR	USA	11.0
Jan. 13, 1967	18°30'	64°38'		(18.2)	Mar. 19, 1967	18°22'	68°35'		15.5	HL	Dom. R.	2.1
Jan. 26, 1967	18°32'	64°37'		(9.1)	June 18, 1967	32°23'	79°25'		11.6	RR	USA	4.7
Feb. 21, 1967	18°28'	64°45'	228		June 28, 1967	21°42'	86°46'			CL	Cuba	4.1
Jan. 17, 1972	18°30'	64°45'	(200)	(16)	May 16, 1972	26°05'	79°50'	214	20.4	RR	USA	4.0

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[1] RR, rod and reel; CL, criollo line; HL handline

APPENDIX TABLE 8: Sailfish tagged off Venezuela

Release data					Recapture data							
Date	Locality		Estimated size		Date	Locality		Size		Gear[1]	Flag	Months at Liberty
	Lat N	Long W	Length	Weight		Lat N	Long W	Length	Weight			
			cm	*kg*				*cm*	*kg*			
June 19, 1966	(10°50'	67°00')		(16)	June 20, 1966	10°50'	67°00'		20*	PF	Venez.	
June 4, 1966	(10°50'	67°00')	200		July 3, 1966	(10°50'	67°00')		20	RR	Venez.	1.0
April 6, 1966	(10°50'	67°00')		(22.8)	Aug. 7, 1966	(10°50'	67°00')		(28.2)	RR	Venez.	4.0
Sept. 4, 1966	(10°50'	67°00')		(18)	Sept. 9, 1966	(10°50'	67°00')		28.2	PF	Venez.	0.2
Aug. 6, 1966	10°46'	66°55'			Jan. 2, 1967	10°51'	66°57'			LL	Venez.	4.9
Aug. 2, 19-6	(10°50'	67°00')			May 1968	(10°50'	67°00')		29.6	PF	Venez.	21.
Feb. 26, 1966	10°50'	68°05'		21.4	Sept. 20, 1970	11°25'	67°00'		27.3	PF	Venez.	54.8

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[1] RR, rod and reel; LL, Longline; PF, professional fishermen

* Gutted weight

APPENDIX TABLE 9: Sailfish tagged off other areas.

Release data					Recapture data							
Date	Locality		Estimated size		Date	Locality		Size		Gear[1]	Flag	Months at Liberty
	Lat N	Long W	Length	Weight		Lat N	Long W	Length	Weight			
			cm	*kg*				*cm*	*kg*			
May 20, 1961	(18°35'	72°45')		(12.7)	Jan. 21, 1962	(18°35'	72°45')			HL	Haiti	8.1
June 17, 1967	30°10'	81°00'	(170)	(11.4)	Oct. 16, 1967	(26°05'	80°05')	224	17.3	RR	USA	4.0
Oct. 18, 1969	34°57'	75°19'		(18.2)	Mar. 3, 1971	09°05'	55°10'		(13)	PF	Venez.	16.5
Apr. 28, 1971	20°35'	87°05'	214	34.1	Dec. 14, 1971	10°47'	63°09'			PF	Venez	7.6

[1] RR, rod and reel; HL, handline; PF, professional fishermen

Migrations of White Marlin and Blue Marlin in the Western North Atlantic Ocean—Tagging Results Since May, 1970[1]

FRANK J. MATHER, III,[2] JOHN M. MASON, JR., [2] and H. LAWRENCE CLARK[3]

ABSTRACT

Migrations of white marlin, *Tetrapturus albidus* Poey, and blue marlin, *Makaira nigricans* Lacépède, in the western North Atlantic Ocean are discussed in terms of tag returns obtained since the completion of data collection for the paper by Mather, Jones, and Beardsley (1972) in May 1970.

In the period May 1970-May 1972, 2,039 white marlin and 216 blue marlin have been released, and 70 tags from white marlin and 1 from a blue marlin have been returned.

The migratory pattern which had been established for the stock of white marlin summering off the middle Atlantic coast of the United States has been further supported by 54 of 60 new returns from fish released in this area. The six others deviated from this pattern geographically or chronologically, or in both respects. The ten remaining returns were from releases south of lat. 33°N. Five of these fitted with previously observed patterns or individual migrations. The other five were local or scattered, but one of them extended the range of recaptures southeastward to lat. 4°N, long. 40°W.

As previously, times at liberty have been long, and the record has been increased to 58.7 mo. A new calculation, incorporating much additional data, suggests that the annual mortality rate is between 23% and 36%.

The single blue marlin return is the first to show a significant migration—at least 750 nautical miles, from the Bahamas to the Gulf of Mexico—and the dates of release and recapture support the theory of separate populations of blue marlin in the North and South Atlantic. After 30 mo at liberty, this fish weighed twice its estimated weight at release.

Considerable new information on migrations of white marlin and blue marlin in the western North Atlantic Ocean has become available through tags returned since the completion of the paper of Mather, Jones, and Beardsley (1972) in May 1970. In this paper we present these new data in detail, and charts and tables summarizing the total accumulation of tag return data. The discussion covers agreements with, and differences from, the previous findings, and our present opinions about the migrations of these fishes. The estimated mortality rate of tagged and recaptured white marlin has also been revised on the basis of the new data.

Little has been published on the tagging and migrations of Atlantic marlins since the completion of Mather et al. (1972), but we now refer to Earle (1940) for an early tagging effort at Ocean City, Maryland, which had been overlooked by the above authors.

METHODS AND MATERIALS

Marlins and other oceanic fishes have been marked with dart tags (Mather, 1963; Akyüz, 1970) by sport fishermen participating in the Cooperative Game Fish Tagging Program of the Woods Hole Oceanographic Institution (WHOI) since 1954. Tags and tagging equipment are furnished by WHOI, and release data are sent to WHOI. Unfortunately, some difficulties in data retrieval have resulted from failures of participants to send in release data.

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Table 1.—Releases (after slash) and returns (before slash) for white marlin tagged in the western North Atlantic Ocean by year and area of release.

Year	Cape Hatteras to Cape Cod	Oceanic North Atlantic	SE Florida and NW Bahamas	West Indies and vicinity[1]	Gulf of Mexico	Caribbean		Total
						SE	NW	
1954	0/4	—	—	—	—	—	—	0/4
1955	1/116	—	—	0/8	0/21	—	—	1/145
1956	1/402	—	—	0/3	0/8	—	—	1/413
1957	0/144	0/1	—	—	—	—	—	0/145
1958	0/41	—	—	—	—	—	—	0/41
1959	0/200	—	—	—	—	0/2	—	0/202
1960	0/98	—	0/4	0/1	0/4	0/4	—	0/111
1961	2/199	—	0/13	0/9	0/11	0/30	—	2/262
1962	4/342	—	0/41	—	0/4	—	—	4/387
1963	4/612	0/3	0/35	—	0/10	—	—	4/660
1964	12/441	0/5	1/67	—	0/13	—	—	13/526
1965	6/278	—	0/67	0/5	0/10	2/25	—	8/385
1966	11/272	0/6	1/54	0/4	0/23	2/149		14/508
1967	6/277	—	0/88	0/7	1/46	0/103	—	7/521
1968	18/701	—	1/95	0/16	0/56	0/16	—	19/884
1969	20/1,216	—	2/86	0/18	2/35	2/46	—	26/1,401
1970	16/838	—	2/49	0/15	0/24	0/17	0/4	18/947
1971	12/823	—	0/56	0/20	0/18	0/95	0/4	12/1,016
[2]1972	0/18	—	0/36	0/6	0/4	0/1	0/1	0/66
Unknown	5/5	—	—	—	1/1	—	—	6/6
Total	118/7,027	0/15	7/691	0/112	4/288	6/488	0/9	135/8,630

[1] All releases after 1961 were off the Virgin Islands.
[2] Through 20 July.

From May 1970 through May 1972, 2,039 white marlin and 216 blue marlin were tagged in the western North Atlantic. From these and earlier releases, 70 valid returns from white marlin, and one from a blue marlin, were received between May 1970 and 15 July 1972. These brought the cumulative totals to 8,630 releases and 135 valid returns for white marlin and 702 releases and 4 valid returns for blue marlin. In addition, correct recapture data for one earlier white marlin return were obtained and the probable origin of a plastic ring found on the bill of a white marlin caught in July 1959 has been traced. Damaged or incomplete tags or reports of tags recovered but not returned from 2 white marlin and 1 blue marlin were also received.

The release and recapture data for the new white marlin returns, and the corrected data for one of those previously reported, are shown in the Appendix, along with the data for the blue marlin returns. The total accumulated data are summarized in tables and charts as noted in the text.

WHITE MARLIN

Migrations

The 70 new returns from white marlin added considerably to the information obtained from the 65 tags returned in the 16 previous years (Mather et al., 1972). The majority of the releases (1,687) again occurred on the continental shelf between Cape Hatteras and Cape Cod (Table 1). Other release sites were off the northwestern Bahamas and southeastern Florida (140), off Venezuela (114), in the Gulf of Mexico (49), near the West Indies (the Virgin Islands and Puerto Rico) (41), and off the Yucatan Peninsula (9).

All of the recaptures were again in the North Atlantic west of long. 35°W, but their range was extended northward nearly to lat. 43°N, and southeastward to lat. 4°N, long. 40°W. Also, the first three recaptures in the Gulf of Mexico of fish tagged in the Cape Hatteras-Cape Cod area were

Table 2.—Returns from tagged white marlin, by fishery and nationality of recapturing vessel. Returns in Column A were listed by Mather et al., 1972; those in column B were received subsequently.

Type of fishery	Country	Number of returns		
		A	B	Total
Sport fishery (rod and reel)	United States	24	20	44
	Jamaica		1	1
	Venezuela		1	1
Total		24	22	46
Commercial fishery (Japanese and modified longlines, handlines)	Canada	1	2	3
	Cuba	14	5	19
	France	1		1
	Japan	13	30	43
	Norway	2		2
	South Korea	2	5	7
	United States	1		1
	Venezuela	7	6	13
Total		41	48	89
Grand total		65	70	135

recorded. Much new information was gained on the offshore movements of white marlin from the continental shelf in the latter area in September and October. Although most of the returns from this group of fish fitted the pattern proposed for it by Mather et al. (1972), the first major deviations from this pattern were noted. Likewise, some of the returns from releases in southern waters fitted with previous indications, but a few did not.

As in the earlier years, about two-thirds of the recent white marlin returns were from commercial fisheries, and about one-third from sport fisheries (Table 2). In contrast to the earlier period, however, 30 of the commercial returns (over half of the total) were from the Japanese longline fishery, while the Cuban, South Korean, and Venezuelan fisheries each returned 5 or 6 tags. The increase in Japanese returns was due largely to a very heavy concentration of effort in September and October 1971 in the offshore waters between Cape Hatteras and Georges Bank, which produced 17 returns, and to possibly increased effort in the Gulf of Mexico in the late spring and summer of 1971, when 5 tags were recovered.

As in Mather et al. (1972), the returns are divided into four groups, according to release and recapture areas. The boundaries of these areas have been changed slightly from those used by Mather et al. (1972) in order to obtain better seasonal separation of returns, but these changes do not alter the grouping of returns in that paper. The areas (Fig. 1) are as follows:

Area A—north of lat. 33°N,
Area B—lat. 18°N to lat. 33°N,
Area C—south of lat. 18°N.

Sixty of the new returns were from releases on the continental shelf between Cape Hatteras and Cape Cod (Area A), bringing the total for this group to 118. Thirty-six of these were recaptured in the warm season (June-October) in Area A (Group A), 16 in Area B (1 in January, 37 in March-August) (Group B), and 8 in Area C (October-May) (Group C) bringing the respective totals to 60, 38, and 20. Ten of the new recaptures were from releases in Areas B and C (south of lat. 33°N) (Group D) bringing the total for this group to 17. The recaptures in these four groups are discussed below.

Group A.—The new recaptures in Group A (Fig. 1, Appendix Table 1) comprise 19 from inside the 1,000 fathom (1,830 m) contour (June-October) and 17 from outside it (June, July, September, October) bringing the respective totals to 41 and 19 (Appendix Table 1).

The new recaptures inside the 1,000 fathom contour give further evidence of the movements of fish within this area, and also of the regular seasonal return of fish to it, often during several summers.

The new recaptures (3 in June, 2 in July, 4 in August, 9 in September, and 1 in October) spread over more of the year than the earlier ones (2 in July, 17 in August, and 3 in September). The new recaptures in June and September were from sportfishing boats, but the one in October was from a longliner. A new recapture at the edge of the Nova Scotia Banks in August was north and east of any previously recorded on the continental shelf. Like an earlier return from the edge of Georges Bank, this merely reflects the sparsely documented (Leim and Scott, 1966) fact that, whereas the coastal occurrence of white marlin ends at Cape Cod, the species occurs far to the east and north, along the edges of the banks, during the summer.

The recaptures within the year of release (Fig. 2) show that the fish move extensively, and in various directions, within this summer habitat. Those in subsequent years show that fish return to the area seasonally with considerable regularity, and may be

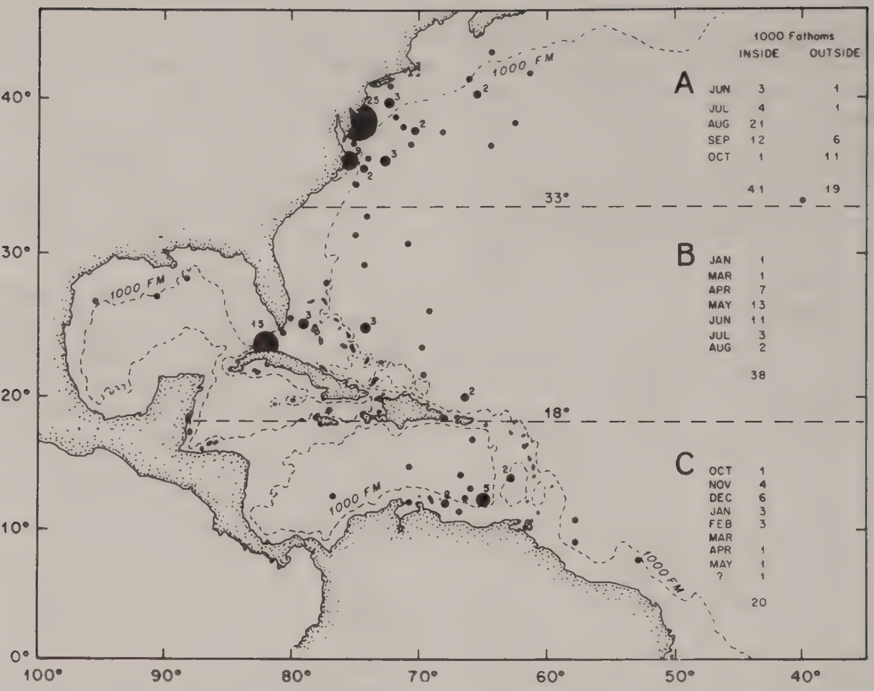
1000 Fathoms
INSIDE OUTSIDE
A
JUN 3 1
JUL 4 1
AUG 21
SEP 12 6
OCT 1 11
41 19
B
JAN 1
MAR 1
APR 7
MAY 13
JUN 11
JUL 3
AUG 2
38
C
OCT 1
NOV 4
DEC 6
JAN 3
FEB 3
MAR
APR 1
MAY 1
? 1
20
33°
18°
1000 FM
40°
30°
20°
10°
0°
100°
90°
80°
70°
60°
50°
40°

Figure 1.—Location of recaptures of white marlin tagged in the western North Atlantic Ocean north of lat. 33°N between Cape Hatteras, N.C., and Cape Cod, Mass., in summer. The frequency of recaptures by months in each area is shown. The number of recaptures at each site is indicated by the size of the dot and, if more than 1, by the adjacent number.

available to fishing there during as many as six seasons. This was shown by a recapture in June 1972 of a fish which had been released in August 1967. These results suggest that most of the white marlin which occur in summer in this area are of a single (but not necessarily genetically distinct) stock. We will tentatively name this the "middle Atlantic" stock, after its summer habitat off the middle Atlantic coast of the United States.

Fifteen of the new returns from outside the 1,000 fathom contour in Area A, which were recaptured in September and October, and the two earlier ones which were recaptured in the same period, give considerable information on how the white marlin leave the inshore fishing grounds between Cape Hatteras and Cape Cod in late summer and early fall (Fig. 3). The other two offshore recaptures, in June and July, give indications of how white marlin approach the shallower waters in spring and early summer. The lack of any offshore returns from Area A in August, when inshore returns are at a maximum, indicates a strong tendency for white marlin to concentrate on the continental shelf in that month.

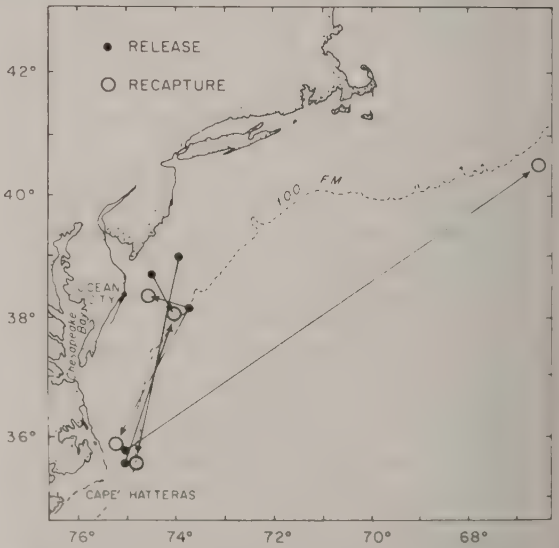
● RELEASE
○ RECAPTURE
100 FM
OCEAN CITY
Chesapeake Bay
CAPE HATTERAS
42°
40°
38°
36°
76°
74°
72°
70°
68°

Figure 2.—Local movements of tagged white marlin inside the 1,000 fathom contour between Cape Hatteras and Georges Bank. Releases were in July (4) and August (2); returns were in August (5) and September (1). Recaptures in years subsequent to year of release are not shown.

A total of 7 recaptures in September and October show "direct" off-shore migrations (indicated by arrows connecting release area and recapture location in Fig. 3) by fish which had been tagged during the summer of, or immediately preceding, their recapture. Eight other offshore recaptures in the same months were of fish which had been tagged in the summers of previous years. These fish presumably had returned to the general release area, and departed from it, in the summer of the year in which they were recaptured. The recaptures are widely scattered, but show a general tendency to migrate into deeper water in directions predominantly between east and south.

The single offshore recaptures in June and July were probably of fish which were approaching the summering areas on the continental shelf off the middle Atlantic coast and on the edge of the Nova Scotia Banks, respectively. It should be noted, however, that Japanese longline vessels take small catches of white marlin (less than 0.5 fish per 100 hooks) in these offshore waters during the summer months (Mather et al., 1972).

Group B.—Twelve of the 16 new recaptures in Group B (released in Area A and recaptured in Area B) (Fig. 1, Appendix Table 2) fitted the pattern proposed by Mather et al., 1972, but the other 4 deviated from it considerably. The new recaptures were in January (1), March (1), April (2), May (5), June (5), and August (2). The earlier recaptures had been in April (5), May (8), June (6), and July (3). The recaptures in January and August differ greatly from previous results. The three previous January recaptures of fish tagged in Area A had been about 20° farther south, in Area C, and the 21 other August recoveries of fish tagged in Area A were in the release area. Three of the new recoveries were in the Gulf of Mexico in 1971, where, with the exception of the immediate vicinity of Havana, no white marlin tagged in northern waters had previously been recaptured. Data on the effort of the Japanese longline fishery in 1971 will help to determine whether these returns from the Gulf of Mexico represent an unusual migration by white marlin from Area A, or merely reflect an unusual amount of fishing effort in the Gulf,[3] in that year. The fish recaptured in the Gulf in June might possibly have continued its return migration to Area A, but it seems most probable that the two which were recaptured in August had shifted their summer habitat from Area A to the Gulf of Mexico. The three earlier July recaptures off Havana of fish which had been tagged in Area A also suggest that not all of the fish which have summered in the Cape Cod-Cape Hatteras area return there in succeeding summers.

Six of the new recaptures were in the Straits of Florida in April-June, bringing to 20 the total number of spring and early summer recaptures there of Group B fish. This is further evidence that an important component of the "middle Atlantic" white marlin stock passes northward through the Yucatan Channel and the Straits of Florida in spring.

There is also further evidence that another sizeable component of this stock migrates northward or northwestward in Atlantic waters off the Greater Antilles and east and north of the Bahamas. Six new recoveries of Group B fish occurred in this area—1 in January, 1 in March, 2 in May, and 2 in June. The earlier returns in the area included 1 in April, 3 in May, and 3 in June. The return in March represents a slight, but not surprising, increase in the period of recapture of Group B fish, but, as noted previously, the recapture in January differs radically from all of our previous results.

A new recapture in May in the Mona Passage is most interesting since it indicates that components of the northward spring migration of "middle Atlantic" white marlin from Area C traverse the passages between the Greater Antilles, as well as the Yucatan Channel and the waters along the Atlantic sides of the islands.

Group C.—Two of the 8 new returns in Group C (fish released in Area A and recaptured in Area C) (Fig. 1, Appendix Table 3) extend the period of recoveries for this group well into the spring. The new recaptures include 2 in December, 2 in January, 1 in February, 1 in April, 1 in May, and 1 at an unknown date. The earlier returns comprised 1 in October, 4 in November, 4 in December, 1 in January, and 2 in February. Unfortunately, it has been impossible to obtain exact dates for some of the recaptures in this area, and some of the estimated dates may be in error. The dates of recaptures of "middle Atlantic" fish in Area B, however, are not inconsistent with some of them remaining in Area C into April or even May.

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[3] Dr. Eiji Hanamoto (pers. comm.) has informed us that an unusually large number of Japanese longline vessels fished in the Gulf of Mexico in the summer of 1971.

Group D.—Seven of the 10 new returns in Group D (white marlin tagged in Areas B and C, and recaptured in any area) (Figs. 1 and 4, Appendix Table 4) were consistent with previous results, but three indicated migratory tendencies which had not previously been noted.

Two fish tagged off the northwestern Bahamas in spring were recaptured off Virginia in September, fitting well with our pattern for "middle Atlantic" white marlin. Another tagged in the same area in late winter was recaptured in the western Gulf of Mexico in June and one tagged in the northwestern Gulf in July was recaptured off Havana in June. Both of these support previous indications of seasonal migrations between sojourns in the Gulf of Mexico in the warm season and in the Straits of Florida and off the northwestern Bahamas in the cold season. There was also a local recapture in August in the north central Gulf from a release there at an unknown date, but in the warm season.

There were three recaptures from releases in August and September off Venezuela. One of these was local in a subsequent August, and one was off the Guianas in November, closely approximating an August-December migration between these areas which had been recorded previously. The third differed somewhat in that it was recaptured north of the release area in January. Evidently, this fish had merely moved offshore into deeper water in the fall, rather than migrating to the eastward as had the ones recaptured in November and December off the Guianas.

The most surprising of the new Group D returns was for a fish released off the northwestern Bahamas in April and recaptured 600 miles ENE of the mouth of the Amazon River in September. This has no apparent resemblance to any of the migratory tendencies indicated by other returns. This migration of about 2,700 nautical miles is the longest yet recorded for a white marlin, and is the closest approach to the South Atlantic that has been made by a white marlin tagged in the North Atlantic. Ueyanagi et al. (1970) and Mather et al. (1972),

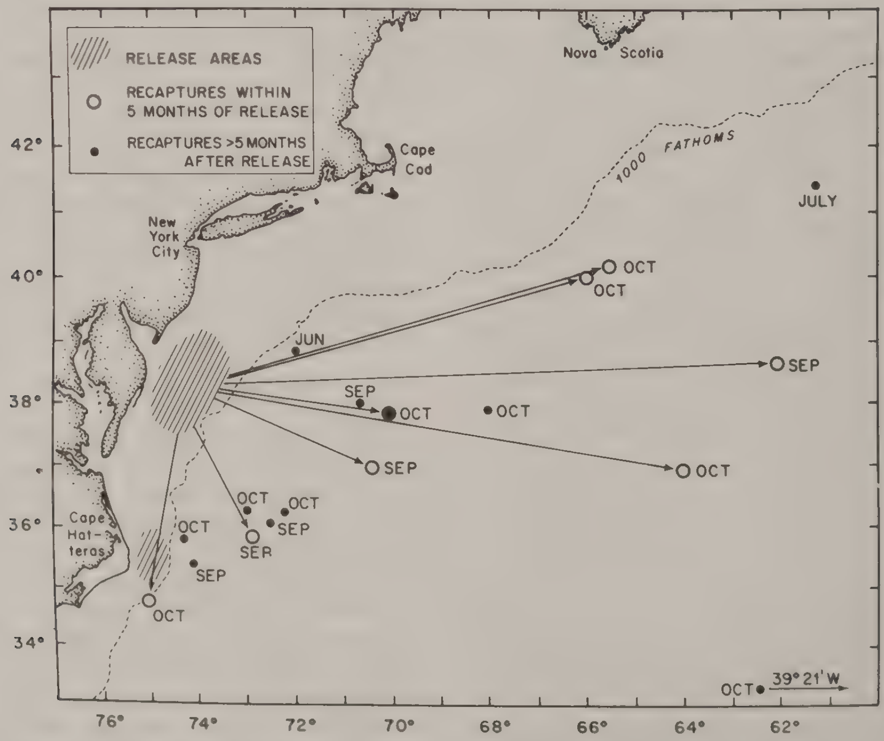
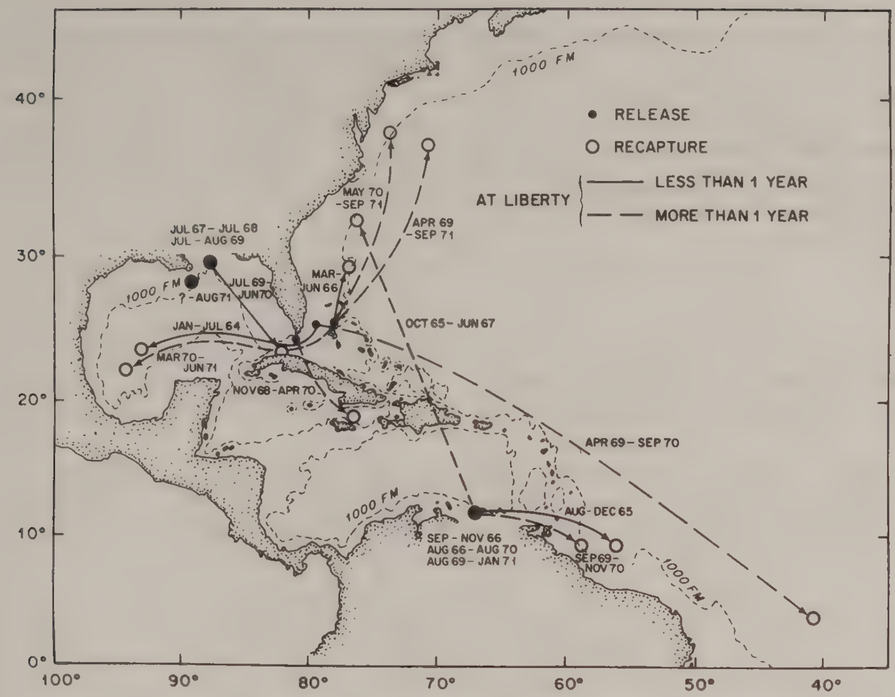


Figure 3.—Recaptures outside the 1,000 fathom contour and north of lat. 33°N of white marlin tagged in summer between Cape Hatteras and Cape Cod.



40°
30°
20°
10°
0°
100°
90°
80°
70°
60°
50°
40°
1000 FM
● RELEASE
○ RECAPTURE
AT LIBERTY
LESS THAN 1 YEAR
MORE THAN 1 YEAR
MAY 70 -SEP 71
APR 69 -SEP 71
JUL 67 - JUL 68
JUL - AUG 69
MAR-JUN 66
JUL 69-JUN70
?-AUG71
JAN-JUL 64
MAR70-JUN71
NOV68-APR70
OCT 65- JUN 67
APR 69-SEP 70
AUG-DEC 65
SEP - NOV 66
AUG 66 - AUG 70
AUG 69 - JAN 71
SEP69-NOV70

Figure 4.—Locations of releases and recaptures of white marlin tagged in the western North Atlantic Ocean south of lat. 33°N. The months and years of release and recapture are shown in that order for each return.

both concluded that the white marlin of the North Atlantic and those of the South Atlantic constituted separate spawning populations.

The migration from off southeastern Florida in November to north of Jamaica in April likewise bears no apparent relationship to our other results. Much more tagging in southern waters is needed to solve the complex problems of stock identification and migratory patterns of the white marlin which occur there.

Growth and Life Span

Reliable growth data cannot be obtained from our tagging results since the sizes of fish when released are estimated, and it is even difficult to assess the quality of the size data accompanying returned tags. Nevertheless, some general conclusions may be drawn. White marlin usually recruit to the fishery, at least in the Maryland-New Jersey area where most of the tagging was done, at sizes of about 15 kg (de Sylva and Davis, 1963). It can thus be assumed that most of the white marlin tagged were of this size, or larger. Eleven tagged white marlin have been recaptured after periods of 3-6 yr at liberty, and none of their reported weights at recapture exceeded 30 kg. The maximum weight recorded for white marlin is 73 kg (International Game Fish Association, 1972). It thus appears that white marlin do not grow very rapidly after recruitment into the sport fishery.

Despite the increased volume of returns, which perhaps indicates increased fishing pressure, times at liberty have continued to be very long (Table 3). Eleven of the new returns were from fish which had been at liberty for more than 30 mo. The times at liberty for two of these, 55.2 and 58.7 mo, are the longest of which we have positive knowledge for any tagged istiophorid fish. A much greater time at liberty, however, may have been enjoyed by a white marlin which was recaptured off Montauk, Long Island, New York, in July 1959. A red plastic ring which was found on the bill of this fish was returned to us. We recently found reference to the use of such rings to mark white marlin at Ocean City, Maryland, in 1939 (Earle, 1940). We checked with various captains who were involved in this program and Captain Louis S. Parsons reported that he had used some of these rings in the seasons of 1947 and 1948. Unfortunately, the ring carried no serial number by which the release data could be established with certainty. Thus the new returns strongly support the opinion of Mather et al. (1972) that the white marlin is much longer lived that was supposed before the work of de Sylva and Davis (1963) and our tagging results were available. It is still impossible, however, to estimate the total life span of the species.

Mortality

Since numerous new tag returns have been obtained, the indicated mortality rate and the coefficient of instantaneous mortality for recaptured white marlin which had been calculated by Mather et al. (1972) from recaptures in groups A-C from releases in 1961-1965 have been calculated from recaptures in the same groups from releases in 1961-1967. The same procedures were followed (Table 3, Fig. 5). The new indicated mortality rate is 30% per year, an increase of 3% over the earlier result, with 95% confidence limits of 23% and 36%. The new coefficient of instantaneous total mortality, Z, is 0.35±0.10, as against the earlier figures of 0.32 ±0.17. The addition of the new data has not changed the indicated mortality rate significantly, but has narrowed the confidence limits (14% and

Table 3.—Summary of recaptures of tagged white marlin, to 15 July 1972, by years of release and months at liberty. Numbers of returns outside of parentheses are for Groups A-C; numbers in parentheses are of Group D. Dashed lines enclose data used for mortality estimates.

Year	Number tagged	Number recaptured	Months at large					
			0-12	12-24	24-36	36-48	48-60	unknown
1954	4							
1955	145	1					1	
1956	413	1	1					
1957	145							
1958	41							
1959	202							
1960	111							
1961	262	2			1	1		
1962	387	4		2		2		
1963	660	4	2	1	1			
1964	526	12(1)	6(1)	2	3	1		
1965	385	6(2)	3(1)	2(1)	1			
1966	508	11(3)	4(2)	3	1	1(1)	2	
1967	521	6(1)	1	1(1)	2		2	
1968	884	18(1)	7	5(1)	5	1		
1969	1,401	20(6)	8(2)	7(3)	5(1)			
1970	947	16(2)	9	7(2)				
1971	1,016	12	12					
[1]1972	65							
Unknown	6	5(1)						5(1)
Total	8,629	118(17)	53(6)	30(8)	19(1)	6(1)	5	5(1)
Total (1961-67 only)	3,249	45(7)	16(4)	11(2)	9	5(1)	4	

[1] Through 20 July.

Table 4.—Releases (after slash) and returns (before slash) for blue marlin tagged in the western North Atlantic Ocean by year and area of release.

Year	Hatteras-Delaware	Oceanic North Atlantic	SE Florida	Bahamas	Virgin Islands	Gulf of Mexico Fla.&La.	Gulf of Mexico Texas	Yucatan	Caribbean NW	Caribbean SE	Totals
1954											
1955						0/1			0/6		0/7
1956				0/1		0/2		0/3	0/3		0/9
1957				0/1							0/1
1958				0/1							0/1
1959	0/1										0/1
1960	0/1			0/2						0/2	0/5
1961				0/3							0/3
1962	0/8	0/1		0/4				0/1			0/14
1963	0/62		0/3	0/21		0/2	0/2				0/90
1964	0/15	0/1	0/5	0/34	0/1	0/2					0/58
1965	0/2	0/1	0/1	0/30	0/10	0/1				0/2	0/47
1966	0/1		0/1	0/24	0/6	0/3				1/9	1/44
1967	0/1			0/29	0/8	0/5	0/1				0/44
1968	0/1			1/40	0/23	0/5	0/1				1/70
1969	0/8		0/2	1/38	0/45	1/1	0/5				2/99
1970	0/18			0/21	0/24	0/2	0/2	0/1			0/68
1971	0/37			0/30	0/44	0/3		0/1			0/115
1972	0/5			0/17	0/3	0/1					0/26
Totals	0/160	0/3	0/12	2/296	0/164	1/28	0/11	0/6	0/9	1/13	4/702

[1] Through 20 July.

39% in the earlier calculation). These results support our belief that the returns do have biological significance. These relatively low mortality rates are further indications of the longevity of the species. They also show that released white marlin have a fair chance of continued reproduction, and of being available to fisheries for an appreciable period.

BLUE MARLIN

New information on migrations of blue marlin is limited to one valid return[4] and one for which the release data are uncertain (Table 4, Fig. 6, Appendix Table 5). The valid return shows a migration from the northwestern Bahamas in February 1969, to the central Gulf of Mexico in August 1971. Similar migrations have been noted in this report and by Mather et al. (1972) for white marlin, and by Mather, Tabb, Mason, and Clark (1974) for sailfish,

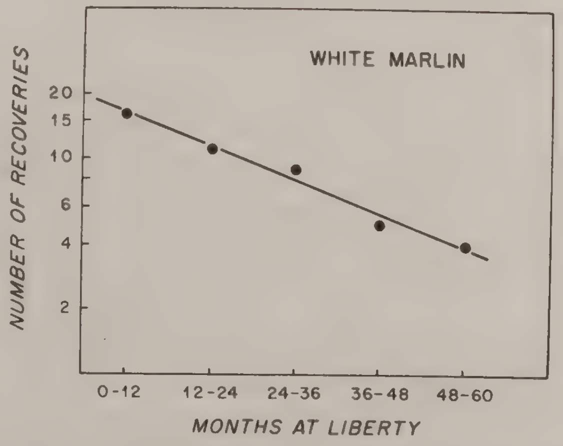


Figure 5.—Number of returns from white marlin tagged in 1961-67 in waters north of lat. 33°N, plotted by time at liberty.

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[4] Another tag from a blue marlin was returned after this manuscript was completed. This fish was released near Walkers Cay (northern tip of the Bahamas) in July 1971, and recaptured off Elbow Cay, Cay Sal Bank, Straits of Florida, in July 1972. Its weight was estimated at 68 kg when released, and it weighed 86 kg when recaptured.

Istiophorus platypterus. The data for this return support the opinion of Mather et al. (1972) that the concentrations of blue marlin in the western North Atlantic from June through October, and in the western and central South Atlantic in February, March, and April, represent separate populations. This return also gives the first available indication of the growth rate of Atlantic blue marlin. The fish's weight when released was estimated at 200 pounds (90 kg), and it weighed 163 kg (eviscerated) when recaptured after 30 mo at liberty. Since estimates of the weight of fish when tagged have usually proved to be high, it seems probable that this fish doubled its weight in two and a half years. The other return was from a 165 pound (75 kg) blue marlin recaptured at Cape Hatteras, North Carolina, in August 1970. Unfortunately, the serial number on the streamer was illegible and the dart, which also carried the serial number, was not returned. To our knowledge, only 14 blue marlin in this size range or smaller had been marked prior to this recapture with the type tag returned from this fish. Six of these were released off the Virgin Islands, June-November 1969, and 8 off the northwestern Bahamas and southeastern Florida, April-December 1969. It is highly probable that the recaptured fish was one of these, but there is also a possibility that the sportsman who tagged it neglected to report the data.

Tag return rates for blue marlin in recent years have been about 1%. This low rate and the small number (usually less than 100) tagged each year have made the accumulation of tag return data for this species extremely slow. Future tagging efforts would be most effective if concentrated on marking as many small individuals as possible.

SUMMARY

White Marlin

A. Fish which summer between Cape Hatteras and Cape Cod.

    1. These fish move offshore, mainly in easterly to southerly directions, in late summer and early fall.
    2. Most of these fish winter off northern South America and some may remain there

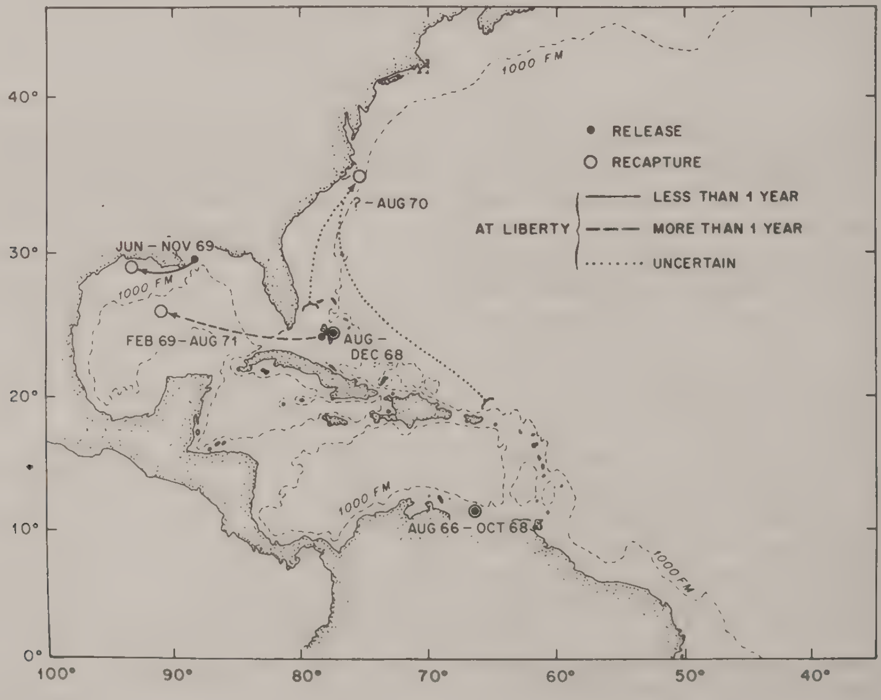

Figure 6.—Locations of releases and recaptures for blue marlin tagged in the western North Atlantic Ocean. The months and years of release and recapture are shown in that order for each return.

into May instead of only into February.

3. Some of these fish winter as far north as off the Carolinas.

4. These fish migrate northward in spring through the Yucatan Channel and the Straits of Florida and through the Atlantic waters off the West Indies and the Bahamas.

5. Some of them migrate northward through the Mona Passage.

6. Some of them were recaptured in the Gulf of Mexico in the spring and summer of 1971 for the first time. It is uncertain whether this represents an unusual migration, or unusually heavy fishing effort.

7. Most of the white marlin in this group return to the summering area repeatedly, but some do not.

8. Two fish tagged off the northwestern Bahamas in spring have followed the migratory pattern of this group to its summering area.

B. Fish of other groups.

1. Many white marlin summer in the Gulf of Mexico and winter in the Straits of Florida or among the northwestern Bahamas.

2. Some of the fish which concentrate off Venezuela in late summer and early fall move to off the Guianas in late fall; others may merely move northward to deeper water.

3. The longest migration recorded for a white marlin was from off the northwestern Bahamas to about 600 miles east-northeast of the mouth of the Amazon, a distance of about 2,700 nautical miles. This migration has no apparent relation to the others recorded by tag returns and is the closest approach to the South Atlantic by a white marlin tagged in the North Atlantic.

C. General.

1. The longevity of the species has been further demonstrated by record times at liberty for tagged fish of 55.2 and 58.7 mo.

2. A new calculation using more tag return data shows an estimated mortality rate of 30%.

3. The white marlin in the North Atlantic are separate from those of the South Atlantic.

Blue Marlin

1. A group of blue marlin may spend the warm season in the Gulf of Mexico and the cold season among the northwestern Bahamas.

2. A tagged blue marlin weighing about 90 kg when released approximately doubled its weight in 30 mo at liberty.

ACKNOWLEDGMENTS

The authors are most grateful to all the organizations and individuals who have assisted this research.

The principal financial support of this work since 1956 has been from the National Science Foundation (Grants G-861, G-2102, G-8339, G-6172, G-19601, GB-3464 and GH-82), the Bureau of Commercial Fisheries (now National Marine Fisheries Service) (Contracts 14-17-0007-272, -547, -870, -975, and -1110), and the Office of Sea Grant, National Oceanic and Atmospheric Administration, U.S. Department of Commerce (Grant GH-82). Important additional support has been received from the Sport Fishing Institute; the Charles W. Brown, Jr., Memorial Foundation; the Tournament of Champions (through Mrs. R.C. Kunkel and E. D. Martin); A. Minis, Jr.; the Joseph A. Teti, Jr., Foundation; the Port Aransas Rod and Reel Club; P.A.B. Widener; the Jersey Cape Fishing Tournament; the Associates of the Woods Hole Oceanographic Institution; and many other sportsmen's organizations and individual sportsmen.

The National Marine Fisheries Service and its predecessor, the Bureau of Commercial Fisheries, the Inter-American Tropical Tuna Commission, the Fisheries Research Board of Canada, the Food and Agriculture Organization of the United Nations, and many other national and private research organizations have assisted in the promoting of the tagging of fishes, the collection and processing of data, and the dissemination of information on the program and its results. In particular, Albert C. Jones contributed the mortality estimates for white marlin.

The tagging results were made possible by the thousands of anglers, captains, and mates who have tagged, and released many of their catches, and the clubs, committees, and individuals who have encouraged tagging. We regret that space does not permit individual acknowledgments here; the major participants are listed in the informal progress reports which are issued periodically by the Woods

Hole Oceanographic Institution. The press and the broadcasting media have also done much to encourage tagging and the return of tags.

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APPENDIX

Release and recapture data for marlins tagged in the western North Atlantic Ocean are presented in five Appendix Tables. Data for White marlin recaptured between May, 1970, and July 15, 1972, are grouped in four tables according to release and recapture areas. Corrected data for one white marlin return listed by Mather et al. (1972) are included. The fifth table shows all the blue marlin returns obtained to date. In each table, the returns are listed in order of date of recapture. Although anglers estimated lengths in inches and weights in pounds, we have converted them to metric units. Data in parentheses are estimated or approximate.

APPENDIX TABLE 1.--Group A: White marlin tagged and recaptured north of lat 33°N

Release data					Recapture data							
Date	Locality		Estimated size		Date	Locality		Size		Gear[1]	Flag	Months at liberty
	Lat N	Long W	Length	Weight		Lat N	Long W	Length	Weight			
			cm	*kg*				*cm*	*kg*			
July 24, 1968	38°13'	73°51'	(210)		June 16, 1970	38°50'	71°50'	220	(43)	LL	Can.	22.8
July 5, 1969	36°15'	75°00'		(16)	July 13, 1970	35°47'	74°54'		(20)	RR	U.S.	0.3
July 4, 1969	36°24'	74°43'		(27)	July 14, 1970	38°02'	74°07'	220		RR	U.S.	12.3
July 12, 1968	38°08'	74°00'		(25)	Aug. 5, 1970	42°46'	64°15'	190	(25)	LL	Can.	24.8
Sept. 9, 1967	37°48'	74°08'		(20)	Aug. 19, 1970	37°48'	74°08'	230	27	RR	U.S.	35.4
July 3, 1969	38°13'	73°51'		(36)	Sept. 15, 1970	37°40'	74°10'	234	39	RR	U.S.	14.4
Unknown	(36°00'	75°00')			Sept. 15, 1970	37°29'	74°30'	(200)	(20)	RR	U.S.	
Aug. 15, 1970	(36°20'	75°06')		(23)	Sept. 15, 1970	(36°00'	75°00')			RR	U.S.	1.0
Sept. 16, 1970	(36°00'	75°00')		(18)	Sept. 16, 1970	35°53'	74°43'	(200)	(16)	RR	U.S.	0
Aug. 3, 1969	37°51'	74°12'	(220)		Sept. 18, 1970	37°32'	74°30'	(213)	39.8	RR	U.S.	13.5
Aug. 10, 1968	37°43'	74°04'		(16)	Sept. 26, 1970	39°40'	72°32'	203	20	RR	U.S.	25.6
Aug. 4, 1966	38°03'	74°52'		(18)	Oct. 25, 1970	37°53'	68°05'	160	14	LL	Jap.	50.8
Aug. 29, 1970	38°30'	73°30'		(27)	June 19, 1971	38°15'	73°50'	203	25.4	RR	U.S.	9.7
July 23, 1970	38°15'	73°50'	(210)	(23)	July 10, 1971	41°23'	61°18'		19.5	LL	Jap.	11.6
Aug. 31, 1969	(38°20'	74°30')		(16)	Aug. 20, 1971	38°15'	73°50'	203	20.4	RR	U.S.	23.7
(Sept. 9, 1968)	(38°10'	74°30')			Aug. 22, 1971	(38°15'	73°50')	(220)	(29.5)	RR	U.S.	35.5
July 25, 1969	38°10'	74°05'		(20)	Sept. 10, 1971	38°51'	73°14'	218		RR	U.S.	25.6
Unknown					Sept. 14, 1971	38°00'	70°40'	160	(22)	LL	Jap.	
July 23, 1970	38°15'	73°50'			Sept. 14, 1971	36°05'	72°35'			LL	Jap.	13.8
July 21, 1971	35°43'	75°10'		(23)	Sept. 15, 1971	38°15'	74°02'			RR	U.S.	1.8
July 13, 1971	38°15'	73°50'	(200)	(23)	Sept. 15, 1971	35°52'	72°35'			LL	Jap.	2.1
Aug. 29, 1971	37°44'	74°20'		(20)	Sept. 19, 1971	37°00'	70°30'	145	26	LL	Jap.	.7
July 26, 1968	39°45'	71°53'		(20)	Sept. 21, 1971	37°10'	75°25'		29.5	RR	U.S.	37.9
Sept. 21, 1970	35°46'	75°10'	(200)	(32)	Sept. 25, 1971	35°23'	74°08'	140	24*	LL	Jap.	12.1
July 18, 1970	35°50'	74°45'	(200)		Oct. 3, 1971	37°27'	74°15'	150	27	LL	Jap.	14.5
July 16, 1971	38°15'	73°50'		(25)	Oct. 4, 1971	40°08'	65°35'	160	(24)	LL	Jap.	2.6
July 17, 1971	38°15'	73°50'		(25)	Oct. 4, 1971	40°00'	66°00'		(18)	LL	Jap.	2.6
Aug. 20, 1970	37°50'	74°15'		(20)	Oct. 6, 1971	36°15'	73°00'		23	LL	Jap.	13.6
Aug. 16, 1969	38°15'	73°50'	(200)	(19)	Oct. 7, 1971	36°15'	72°15'		25	LL	Jap.	25.7
July 3, 1971	38°12'	74°00'		(23)	Oct. 9. 1971	37°50'	70°05'		20	LL	Jap.	3.2
July 9, 1970	36°15'	74°48'		(23)	Oct. 10, 1971	35°50'	74°20'		25	LL	Jap.	15
Sept. 4, 1971	38°15'	73°50'			Oct. 15, 1971	36°56'	64°07'	200	25	LL	Jap.	.1
Sept. 17, 1971	37°45'	74°10'		(23)	Oct. 17, 1971	34°48'	75°03'	140	19*	LL	Jap.	1.0
Sept. 14, 1970	37°43'	74°20'			Oct. 30, 1971	37°50'	70°05'		19	LL	Jap.	13.5
Aug. 31, 1969	38°15'	73°85'	(200)		June 19, 1972	35°48'	75°00'		(22)	RR	U.S.	33.6
Aug. 6, 1967	37°53'	74°05'		(18)	June 25, 1972	35°45'	74°53'	203		RR	U.S.	58.7

[1] RR, rod and reel; LL, longline; CL, crillo line

* Gutted weight

APPENDIX TABLE 2.--Group B: White marlin tagged north of lat 33°N and recaptured between 18°N and lat 33°N.

Release data					Recapture data							
Date	Locality		Estimated size		Date	Locality		Size		Gear[1]	Flag	Months at Liberty
	Lat N	Long W	Length	Weight		Lat N	Long W	Length	Weight			
			cm	*kg*				*cm*	*kg*			
+Sept. 17, 1967	38°15'	73°50'			May 15, 1968	28°06'	77°16'		15	LL	Cuba	7.9
July 15, 1968	38°13'	73°51'		(20)	May 4, 1969	20°25'	67°00'	150	(10)	LL	Jap.	9.6
Summer 1965	38°10'	74°30'			April 16, 1970	23°14'	82°46'			CL	Cuba	
Aug. 16, 1969	38°00'	74°11'		(20)	May 7, 1970	30°30'	70°30'	195	25	LL	Kor.	8.7
Aug. 2, 1969	36°06'	75°05'	(160)		June 1, 1970	25°08'	74°01'		18.3	LL		10
Sept. 14, 1968	36°28'	74°50'			June 13, 1970	21°38'	69°45'	195	20.5	LL	Jap.	21.0
July 5, 1968	38°15'	73°50'		(25)	Jan. 26, 1971	32°37'	73°59'	180	48	LL	Jap.	30.8
July 21, 1968	38°13'	73°51'		(20)	March 26, 1971	25°16'	68°47'	183.6	19.8	LL	Kor.	32.2
Aug. 26, 1969	35°48'	75°15'		(20)	May 15, 1971	(23°20'	82°20')			LL	Cuba	20.6
July 25, 1970	38°30'	73°30'		(23)	June 5, 1971	25°51'	79°56'		(20)	RR	U.S.	10.4
Sept. 11, 1969	38°15'	75°00'		(22)	June 11, 1971	(23°20'	82°20')			LL	Cuba	21
Sept. 16, 1970	36°00'	75°00'	(180)	(23)	June 19, 1971	26°36'	95°10'			LL	Jap.	9.1
Sept. 18, 1970	38°05'	74°03'		(17)	Aug. 10, 1971	27°00'	90°40'		16*	LL	Jap.	10.7
July 26, 1969	38°15'	73°50'		(20)	Aug. 13, 1971	28°10'	88°02'	150		LL	Jap.	24.6
July 11, 1971	38°07'	73°57'	(150)	(16)	April 8, 1972	25°45'	79°20'	185	24	RR	U.S.	8.9
Aug. 9, 1971	38°30'	73°30'		(23)	May 28, 1972	18°22'	68°12'		19.5	RR	U.S.	9.6
July 13, 1971	38°15'	73°50'	(200)	(25)	May 30, 1972	23°10'	82°23'	225	32	HL	Cuba	10

[1] RR, rod and reel; LL longline; CL, criollo line; HL, hand line

* Gutted weight

+ Correction - previously recorded (Mather et al, 1972) as recaptured (May 15, 1969)

APPENDIX TABLE 3.--Group C: White marlin tagged north of lat 33°N and recaptured south of lat 18°N.

Release data					Recapture data							
Date	Locality		Estimated size		Date	Locality		Size		Gear[1]	Flag	Months at Liberty
	Lat N	Long W	Length	Weight		Lat N	Long W	Length	Weight			
			cm	*kg*				*cm*	*kg*			
Aug. 31, 1969	36°25'	74°44'		(14)	(May 30, 1970)	12°20'	66°10'		(30)	LL	Venez.	(8.9)
July 16, 1966	39°00'	74°10'		(20)	Dec. 2, 1970	14°10'	65°44'		15	LL	Kor.	52.6
Sept. 9, 1970	36°20'	75°00'	(200)	(24)	Dec. 20, 1970	16°48'	65°23'	175	26.5	LL	Jap.	3.4
Aug 4, 1969	36°06'	74°57'		(17)	Jan. 27, 1971	14°11'	70°04'	(140)		LL	Jap.	17.8
Sept. 2, 1970	(36°50'	75°00')	206	(23)	(Dec. 1971)	(12°50'	66°00')			LL	Venez.	
July 3, 1971	35°48'	74°42'	(180)	(31)	Jan. 7, 1972	09°03'	57°37'		28	LL	Kor.	6.2
July 24, 1969	36°00'	75°00'		(24)	(Feb. 3, 1972)	(12°00'	66°30')			LL	Venez.	(30.5)
Sept. 10, 1967	(38°15'	74°50')		(16)	April, 1972	(11°43'	70°51')		(30)	LL	Venez.	55.2

[1] LL, Longline

APPENDIX TABLE 4.--Group D: White marlin tagged south of lat 33°N.

Release data					Recapture data							
Date	Locality		Estimated size		Date	Locality		Size		Gear[1]	Flag	Months at Liberty
	Lat N	Long W	Length	Weight		Lat N	Long W	Length	Weight			
			cm	kg				cm	kg			
Nov. 2, 1968	25°40'	80°07'		(16)	April 16, 1970	18°32'	76°53'	203	20.9	RR	Jamaica	17.4
July 10, 1969	29°50'	87°00'		(25)	June 14, 1970	23°15'	82°08'		20	CL	Cuba	11.2
Aug. 13, 1966	10°50'	66°50'		(20)	Aug. 8, 1970	10°50'	66°50'		(25)	RR	Venez.	47.9
April 23, 1969	25°43'	79°20'		(16)	Sept. 21, 1970	03°57'	40°20'	185	24	LL	Jap.	17.0
Sept. 11, 1969	(10°50'	66°55')			Nov. 11, 1970	09°00'	59°00'	139.5	13.5*	LL	Venez.	14
Aug. 17, 1969	(10°50'	66°55')		(28)	Jan. 2, 1971	11°50'	67°00'		27.2	LL	Venez.	16.5
March 4, 1970	25°26'	78°06'		(15)	June 14, 1971	22°10'	94°12'	145	22.7	LL	Jap.	15.4
Unknown	(28°40'	88°50')			Aug. 11, 1971	28°15'	89°05'			LL	Jap.	
April 19, 1969	25°26'	78°06'		(30)	Sept. 19, 1971	37°00'	70°30'	148	27	LL	Jap.	29.0
May 16, 1970	25°26'	78°06'	(210)	(36)	Sept. 20, 1971	37°54'	73°32'	140	18	LL	Jap.	16.2

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[1] RR, rod and reel; LL, longline; CL, criollo line;

* Gutted weight

APPENDIX TABLE 5.--Blue marlin.

Release data					Recapture data							
Date	Locality		Estimated size		Date	Locality		Size		Gear[1]	Flag	Months at Liberty
	Lat N	Long W	Length	Weight		Lat N	Long W	Length	Weight			
			cm	kg				cm	kg			
Aug. 20, 1966	(10°50'	66°55')		(83)	Oct. 27, 1968	10°35'	67°05'		98	RR	Venez.	26.2
Aug. 14, 1968	(25°20'	77°58')	(165)	(23)	Dec. 22, 1968	24°45'	77°40'	221	45.5	RR	U.S.	4.3
June 26, 1969	29°40'N	88°30'		(91)	Nov. 27, 1969	29°22'	93°26'		97	ST	U.S.	4
Unknown	(19°00' or (26°00'	65°00') 79°00')			Aug. 29, 1970	35°20'	75°35'	320	75	RR	U.S.	
Feb. 13, 1969	25°25'	78°05'	(270)	91	Aug. 13, 1971	26°30'	91°00'		163*	LL	Jap.	30.0

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[1] RR, rod and reel; LL, longline; ST, shrimp trawl.

* Gutted weight

Migration Patterns of Istiophoridae in the Pacific Ocean as Determined by Cooperative Tagging Programs

JAMES L. SQUIRE, JR.[1]

ABSTRACT

Since 1954, billfish have been tagged by cooperative marine game fish tagging programs in many of the major sportfishing areas of the Pacific. Major locations of tagging have been off southern California, U.S.A., Baja California Sur and mainland Mexico, Panama, and Australia. Two cooperative marine game fish tagging programs have operated in the Pacific, 1) the Cooperative Marine Game Fish Tagging Program, sponsored jointly by the Woods Hole Oceanographic Institution and the National Oceanic and Atmospheric Administration, National Marine Fisheries Service, and 2) a cooperative program conducted by the California Department of Fish and Game.

During 1954-1971, 15,540 billfish were tagged. Records show 9,849 striped marlin *(Tetrapturus audax)*, 4,821 sailfish *(Istiophorus platypterus)*, 622 black marlin *(Makaira indica)*, and 248 blue marlin *(Makaira nigricans)* were tagged during this period. Ninety-seven tag recoveries have been made; these include 85 striped marlin, 10 sailfish, and 2 black marlin. Eighty-one percent of these recoveries were by longline fishing vessels, the remainder by marine sport fishermen.

The tag recovery rates were 0.88% for striped marlin, 0.32% for black marlin, and 0.24% for sailfish.

Four types of tags were used in the two programs. Two types of metal tip dart tags were used by the Woods Hole Oceanographic Institution; metal tipped single- and double-barbed plastic dart tags were used by the National Marine Fisheries Service; and a single-barb plastic dart tag was used by the California Department of Fish and Game. Tag types giving the best recovery rate for striped marlin and sailfish were the plastic single- and double-barbed dart tags.

Recovery data for striped marlin tagged in the eastern Pacific show a movement away from the tip of Baja California in a south to southwest direction in late spring and early summer. Some recoveries were made of fish tagged near the tip of Baja California and recaptured northwest of the tip of Baja California, Mexico. The migration pattern to the south and southwest at this time of the year may be related to spawning. Striped marlin tagged off southern California show a migration to the south in late summer and early fall. Recoveries of striped marlin in the eastern Pacific were generally short-term (average of 89 days) and covered short distances, averaging 281 nautical miles. Only three of 85 tagged striped marlin, and one of two tagged black marlin, were recovered 1,000 nautical miles or more from the site of tagging. The few recoveries of tagged black marlin (2) and sailfish (10) did not provide sufficient data to determine migration patterns for these species.

The tagging or marking of fish is an established method in the study of fish growth, migration, distribution and population structure (Schaefer, Chatwin, and Broadhead, 1961; Beckett, 1970). The concept of utilizing the services of marine anglers in the tagging of large marine game fishes, such as tunas and billfishes, was developed by Frank J. Mather III of the Woods Hole Oceanographic Institution, Woods Hole, Massachusetts. The first cooperative tagging of billfishes in the Pacific Ocean was in 1954 when tagging equipment was furnished by Mather to anglers fishing for billfishes and tunas. Interest in the tagging and releasing of billfishes in the Pacific increased and in 1961 arrangements were made with Mather for the then U.S. Fish and Wildlife Service's Tiburon Marine Laboratory to assume responsibility for the cooperative Marine Game Fish Tagging Program in the Pacific area. This program has recently been transferred to the Department of Commerce, National Marine Fisheries Service, Southwest Fisheries Center, La Jolla Laboratory, La Jolla, California. The Pacific phase of the Cooperative

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[1] NOAA, National Marine Fisheries Service, Southwest Fisheries Center, La Jolla, CA 92037.

Game Fish Tagging Program was assisted by the International Game Fish Association and the Department of Fisheries, Mexico.

The State of California, Department of Fish and Game also participated in a cooperative tagging program for billfishes (striped marlin and sailfish) from 1965 through 1970 with the assistance of anglers representing the Oceanic Research Institute, San Diego, California.

The importance of the istiophorid billfishes, such as striped marlin *(Tetrapturus audax)* and sailfish *(Istiophorus platypterus)* in the eastern Pacific, blue marlin *(Makaira nigricans)* about the Hawaiian Islands (Strasburg, 1969), and black marlin *(Makaira indica)* off Queensland, Australia and throughout the Pacific, as species on which valuable sport fisheries are based upon, is well known. In addition to an extensive sportfishery, these species also assist in supporting an extensive commercial longline fishery throughout the subtropical and tropical Pacific.

The cooperative billfish tagging programs in the Pacific were developed to obtain an adequate understanding of the migratory patterns of billfishes so that ultimately the stocks can be properly managed. The migratory patterns of billfishes in the Pacific are little known. These fishes are caught in quantity primarily with hook and line, either by longlining or by rod and reel. Use of the more efficient longline gear from a research vessel for the purpose of tagging and releasing of billfishes would be costly, and in excess of any funds now available for billfish migration studies. The aid of the marine game fish angler was requested and to date the cooperative tagging programs have accounted for nearly all the billfishes tagged in the Pacific. Bayliff[2] reported tagging of billfishes by research agencies such as the National Marine Fisheries Service, Honolulu Laboratory and the Kanagawa Prefectural Fisheries Research Station in Japan. In 1968 the Honolulu Laboratory tagged 44 striped marlin, 1 blue marlin, and 10 shortbill spearfish. The Japanese Research Station reported tagging 33 striped marlin, 3 blue marlin, and 73 broadbill swordfish *(Xiphias gladius)*. No returns were reported from any of these taggings.

By furnishing tagging equipment to marine game fish anglers who have an interest in the rational conservation of the billfish resources, substantial numbers of billfishes can be tagged in areas of intensive sportfishing for a relatively modest cost. Marine game fishermen have been encouraged to tag and release billfishes through information in the form of written requests, talks before billfishing clubs, posters, and brochures. In addition, posters requesting both sport and commercial fisheries to return tags and advising of a reward are distributed in both the Spanish and Japanese languages.

The major geographical locations of cooperative tagging have been about the tip of Baja California, Mexico; Mazatlán, Mexico; and Cairns, Australia. Other locations where lesser numbers of tagged fish have been released are off southern California and the Hawaiian Islands, U.S.A.; Manzanillo and Acapulco, Mexico; Piñas Bay, Panama; Salinas, Ecuador; Tahiti; and New Zealand.

MATERIALS AND METHODS

The large size and active nature of billfishes require a tag that can be applied while the fish remains in the water. Dart tags were selected because they could be used effectively by billfish anglers inexperienced in tagging fish. All tagging, with the exception of a few striped marlin and swordfish, have been on hook and line caught fish. Some surface-swimming billfishes have been free-tagged by harpooning with a dart tag.

Four types of tags were used by the cooperative programs. The California Department of Fish and Game used the single nylon barb tag with yellow polyvinylchloride tubing bearing the legend, type FT-1 (Fig. 1A). The National Marine Fisheries Service's cooperative program used four types of dart tags: (i) In 1963 a number of type "C" tags (Fig. 1C) were issued. These tags had a stainless steel tip with yellow polyvinyl tubing for the legend and were similar to the type of tags used by the Woods Hole Oceanographic Institution program in the late 1950's and early 1960's. (ii) The FT-1 (Fig. 1A) with a slightly enlarged base on the dart head to prevent the tagging applicator tube from shearing the barb when pressure is applied to insert the tag into the billfish. This tag was recommended for tagging sailfish. (iii) A larger double barbed nylon tag FM-67 (Fig. 1B) with yellow polyvinyl tubing for information was used from 1963 to 1971. (iv) In mid-1971, the stainless steel dart tag, type "H" (Fig. 1D) was introduced. This tag has a nylon, monofilament line extending from the stainless steel barb with a yellow polyvinyl tubing sleeve over the

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[2] Bayliff, William H., et al. 1972. Second interim report of the Working Party on Tuna and Billfish Tagging in the Pacific and Indian Oceans. FAO, unpublished.

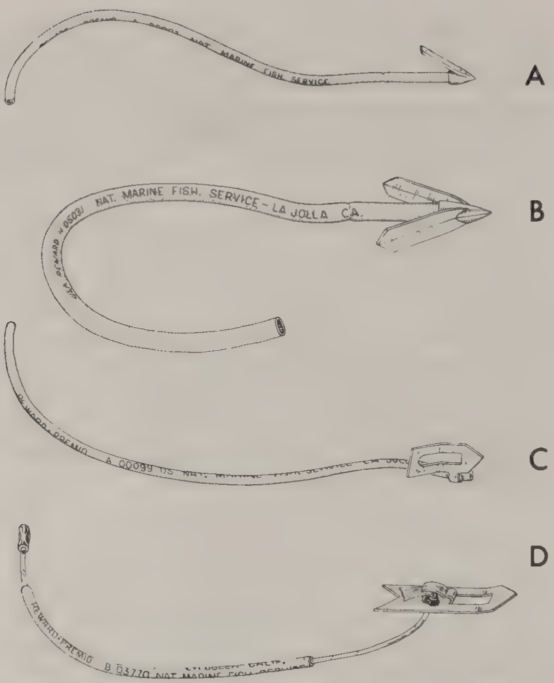

Figure 1.—Types of dart tags used by the cooperative tagging programs.

monofilament for printed information. All tags used by the National Marine Fisheries Service and the California Department of Fish and Game were manufactured by the Floy Tag Manufacturing Company, Seattle, Washington.[3] On all the tags, a serial number and a message are heat-embossed in black. The legend gives an address for return, together with a notice that a reward will be given. In the early years of the cooperative program the Woods Hole Oceanographic program used the type "C" tags (Fig. 1C) in the Pacific. In later years tags of an "H" type were used (Fig. 1D).

Upon bringing the billfish close to the boat the angler was instructed to insert the tag beside the dorsal fin, just posterior of the first dorsal ray, and at an angle so the tubing points in the general direction of the tail. This was done to provide a streamlining effect of the water flow over the tubing. After insertion, the leader was to be cut, thereby releasing the fish and leaving the hook and a portion of the leader attached. If necessary, it was recommended that the billfish be towed forward slowly before release to provide an additional supply of oxygen to assist in reviving the fish.

Tags were attached to a postcard having the serial number of the tag. After tagging the angler was requested to complete the information on tagging date, location, species, estimate of weight, tagger's name and address, and return it to the organization issuing the tag.

TAGGING RESULTS

In the early 1960's, the Japanese longline fleet began fishing near the coasts of North, Central, and South America. The advent of this fishery has provided an invaluable source of billfish tag recoveries. Prior to 1963, a good source of recovery for billfish tags had not existed in the eastern Pacific.

Cooperating marine game fish anglers have tagged 15,540 billfishes in the Pacific since 1954.

Woods Hole Oceanographic Institution records for the period 1954 through 1971, show 3,618 tagged billfish releases (Mather, 1972). The National Marine Fisheries Service program resulted in the tagging and release of 10,964 billfishes. The distribution of tagging effort for the 14,582 billfish tagged by the Woods Hole Oceanographic Institution/National Marine Fisheries Service Cooperative Marine Game Fish Tagging Program included 8,953 striped marlin, 248 blue marlin, 622 black marlin, and 4,759 sailfish. The State of California Department of Fish and Game conducted a cooperative tagging program with selected billfish anglers and this program functioned during the period 1965-1970. Of a total of 958 billfishes tagged, 896 were striped marlin and 62 sailfish.

A total of 9,849 striped marlin, 622 black marlin, 248 blue marlin, and 4,821 sailfish was tagged by the cooperative programs. The totals and numbers of the four species of billfishes tagged per year and the number of recoveries (for each year's tagging) are listed by tagging organization in Table 1.

Recoveries

Between 1954 and 1963, no returns were reported in the Pacific for the 945 billfishes tagged and released. From 1963 through 1971 a total of 97 tagged billfishes was recaptured. Foreign longliners recorded 79 recoveries or 81% of the total. One of these was by a Taiwanese longliner; the others were recovered by Japanese longliners. Marine game fishermen have accounted for 18 recoveries or 19%

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[3] Use of a trade name does not imply endorsement by the National Marine Fisheries Service.

Table 1.—Billfishes tagged and recaptured in the Pacific by cooperative marine game fish tagging programs.

		Species				
Year	Organization	Striped marlin	Black marlin	Blue marlin	Sailfish	Totals
1954	A_1	—	—	—	0/3	0/3
1955	A_1	—	—	—	0/9	0/9
1956	A_1	—	—	—	—	—
1957	A_1	0/17	—	—	0/35	0/52
1958	A_1	0/13	—	—	0/8	0/21
1959	A_1	0/10	—	—	0/124	0/134
1960	A_1	0/2	—	—	0/104	0/106
1961	A	0/87	0/8	—	0/188	0/283
1962	A_1	0/76	0/4	—	0/257	0/337
1963	A_1	1/942	0/37	0/30	0/266	0/1,275
	A_2	0/532	0/1	0/18	0/26	0/577
	B	0/18	—	—	—	0/18
1964	A_1	1/113	0/36	0/12	0/241	1/402
	A_2	4/281	—	0/3	0/268	4/552
	B	4/329	—	—	0/7	4/336
1965	A_1	1/52	0/26	0/4	0/233	1/315
	A_2	6/431	0/6	0/7	2/167	8/611
	B	0/253	—	—	0/18	0/271
1966	A_1	0/47	0/19	0/1	0/124	0/191
	A_2	10/735	—	—	2/283	12/1,018
	B	2/186	—	—	0/31	2/217
1967	A_1	0/31	0/27	—	0/62	0/120
	A_2	19/1,279	0/3	0/23	1/480	20/1,785
	B	0/107	—	—	0/1	0/108
1968	A_1	1/29	0/31	—	0/98	1/158
	A_2	13/1,119	0/13	0/32	2/432	15/1,596
	B	—	—	—	—	—
1969	A_1	0/5	0/36	—	0/78	0/119
	A_2	4/747	1/39	0/31	0/318	5/1,135
	B	1/1	—	—	—	1/1
1970	A_1	0/6	0/19	0/2	0/33	0/60
	A_2	16/989	0/82	—	2/501	18/1,572
	B	0/2	—	—	1/5	1/7
1971	A_1	0/9	—	0/12	0/12	0/33
	A_2	2/1,401	1/235	0/73	0/409	3/2,118
Also 1 shortbill spearfish *(Tetrapturus angustirostris)* tagged						
	B	—	—	—	—	—
Totals		85/9,849	2/622	0/248	10/4,821	97/15,540

NOTE: Releases (right of slash). returns (left of slash) by organization conducting the tagging. Returns are listed by year of recapture for WHOI, NMFS and CF&G lists recapture by year of tagging.

A. Cooperative Marine Game Fish Tagging Program.
A_1 Woods Hole Oceanographic Institution, from 1954.
A_2 National Marine Fisheries Service, from 1963.
B. California Department of Fish and Game.

of the total. The FM-67 and FT-1 tags are buoyant and a number of these have been returned after being picked up on the beach after being used to tag a billfish. These tags may have been lost overboard during the tagging process or may have been shed after tagging. Recoveries were considered valid only when the tag was taken from a recently caught fish.

The Cooperative Marine Game Fish Tagging program (National Marine Fisheries Service —Pacific) issued a conservation certificate to both the tagger and recoverer. A cash reward was paid to the tag recoverer by all three programs.

Table 2 gives the percentage rate of recovery by program, by year, and total recovery rate for each species and for all billfish tagged. Table 3 gives a summation of the rate of return for each of the three cooperative tagging programs.

Tag Performance

For the four types of tags used by the cooperative programs (FT-1, FM-67, C, and H) a comparison of tag performance can be made for the types FT-1 used by the California Department of Fish and Game, and the National Marine Fisheries Service and the Woods Hole Oceanographic Institution.

Recovery data for 10,777 tags used by the National Marine Fisheries Service Cooperative Tagging program and 958 tags used by the California

Department of Fish and Game to tag striped marlin, black marlin, and sailfish were analyzed for the purpose of giving some indication of tag performance. Eighty-two percent of the billfishes were tagged with FM-67 tags, 13.8% with FT-1 tags, 3.4% with the "H" tags, and 0.8% with the "C" tag. There were no recoveries of the "C" tag, and the "H" tag has been used only since mid-1971. The percentage recovery rate by tag type and tagging organization is listed in Table 4.

Hooking mortality undoubtedly accounts for a high tag loss, in addition to unknown losses that occur through tag shedding. The percentage of tag loss for the several types of tags is not known.

Table 2.—Rate of recovery of tagged billfishes.

		Species				
Year	Organization	Striped marlin	Black marlin	Blue marlin	Sailfish	Overall % recovery rate
1963	A_1	0.11%	0.00%	0.00%	0.00%	0.08%
	A_2	0.00	0.00	0.00	0.00	0.00
	B	0.00	—	—	—	0.00
				Annual Overall		0.05%
1964	A_1	0.88	0.00	0.00	0.00	0.25
	A_2	1.42	—	0.00	0.00	0.72
	B	1.21	—	—	0.00	1.20
				Annual Overall		0.70%
1965	A_1	1.92	0.00	0.00	0.00	0.32
	A_2	1.40	0.00	0.00	1.20	1.31
	B	0.00	—	—	0.00	0.00
				Annual Overall		0.75%
1966	A_1	0.00	0.00	0.00	0.00	0.00
	A_2	1.40	—	—	0.71	1.08
	B	1.07	—	—	0.00	0.92
				Annual Overall		0.91%
1967	A_1	0.00	0.00	—	0.00	0.00
	A_2	1.50	0.00	0.00	0.21	1.12
	B	0.00	—	—	0.00	0.00
				Annual Overall		0.99%
1968	A_1	3.44	0.00	—	0.00	0.63
	A_2	1.16	0.00	0.00	0.46	0.94
	B	—	—	—	—	—
				Annual Overall		0.91%
1969	A_1	0.00	0.00	—	0.00	0.00
	A_2	0.53	2.56	0.00	0.00	0.35
	B	100.00	—	—	—	100.00
				Annual Overall		0.40%
1970	A_1	0.00	0.00	0.00	0.00	0.00
	A_2	1.62	0.00	—	0.40	1.15
	B	0.00	—	—	20.00	14.28
				Annual Overall		1.16%
1971	A_1	0.00	—	0.00	0.00	0.00
	A_2	0.14	0.43	0.00	0.00	0.14
	B	—	—	—	—	—
				Annual Overall		0.13%
Totals						
1954-71		0.86%	0.32%	0.00%	0.21%	0.62%
1963-71		0.88%	0.32%	0.00%	0.24%	0.66%

A_1 = Cooperative Marine Game Fish Tagging, Woods Hole Oceanographic Institution.

A_2 = Cooperative Marine Game Fish Tagging, National Marine Fisheries Service.

B = Cooperative Billfish Tagging, California Department of Fish and Game.

— = no billfish tagged.

1954 through 1962 no recoveries reported.

MIGRATORY PATTERNS

Eastern Pacific

Figures 2, 3, 4, and 5 show the tagging and recovery points by quarters for both striped marlin and sailfish in the eastern Pacific. The recovery data from the longline fleet have not been adjusted for fishing effort in the various geographical areas. The commercial longline fishery has expanded to the limits of the fishery in the eastern Pacific and the seasonal distribution of fishing effort is assumed to

Table 3.—Rate of recovery (left figure refers to number of tag recoveries; right figure refers to number of fish tagged and released).

Year	Striped marlin	Black marlin	Blue marlin	Sailfish	Total
Program A_1—Woods Hole Oceanographic Institution					
1954-1971	4/1,439 = 0.28%	0/243 = —%	0/61 = —%	0/1,875 = —%	4/3,618 = 0.11%
Since 1963	4/1,234 = 0.32%	0/231 = —%	0/61 = —%	0/1,147 = —%	4/2,673 = 0.15%
Program A_2—National Marine Fisheries Service					
1963-1971	74/7,514 = 0.98%	2/379 = 0.53%	0/187 = —%	9/2,884 = 0.31%	85/10,964 = 0.78%
Program B—California Department of Fish and Game					
1963-1970	7/896 = 0.78%	—/— = —%	—/— = —%	1/62 = 1.6%	8/958 = 0.84%

Rates of recovery for striped marlin and sailfish combined, 1963-1971:

Program A_1 4/2,673 = 0.15%

A_2 85/10,964 = 0.78%

B 8/958 = 0.84%

Table 4.—Percentage recovery rates for tag types used by the California Department of Fish and Game (CF&G), and National Marine Fisheries Service (NMFS), fish tagged through 1971.

Species	Agency	Type tag	% recovery	
Striped marlin	NMFS	FM67	1.06%	>0.66%
	NMFS	FT-1	0.42	
	CF&G	FT-1	0.80	
	NMFS	H	0.40	
Black marlin	NMFS	FM67	0.32%	
	NMFS	H	1.20	
Sailfish	NMFS	FM67	0.30%	>0.86%
	NMFS	FT-1	0.60	
	CF&G	FT-1	1.60	

be located in areas of greatest concentration and maximum yield.

January, February, March.—During this period striped marlin are commonly taken by the sportfishery off Mazatlán, Mexico, and in lesser numbers off Cabo San Lucas, the southern tip of Baja California Sur, Mexico. Sailfish are not common in the area about the mouth of the Gulf of California during the winter and early spring. The longest distance recovery of a striped marlin was for a fish tagged near the tip of Baja California Sur, Mexico, and recovered 200 nautical miles southwest of the Hawaiian Islands, a distance of 3,120 nautical miles in a period of 3 mo (2/67-5/67). Recoveries of striped marlin tagged off Mazatlán, Mexico, show a west to southwest movement towards the tip of Baja California Sur, and the Revillagigedo Islands, Mexico, respectively. Recoveries of striped marlin tagged about the tip of Baja California Sur, Mexico, show some movement toward the northwest and northeast; however the direction of the movement as indicated by tag recoveries from this area is south through southeast (reference, Fig. 2).

April, May, June.—During late spring and early summer the sportfishery striped marlin catch decreases off Mazatlán and increases about the tip of Baja California Sur, Mexico. Sailfish becomes the dominant species off Mazatlán during this season. A pattern of striped marlin movement, indicated by recoveries, is from about the tip of Baja California southward toward Las Tres Marias and Revillagigedo Islands, Mexico. Striped marlin tagged

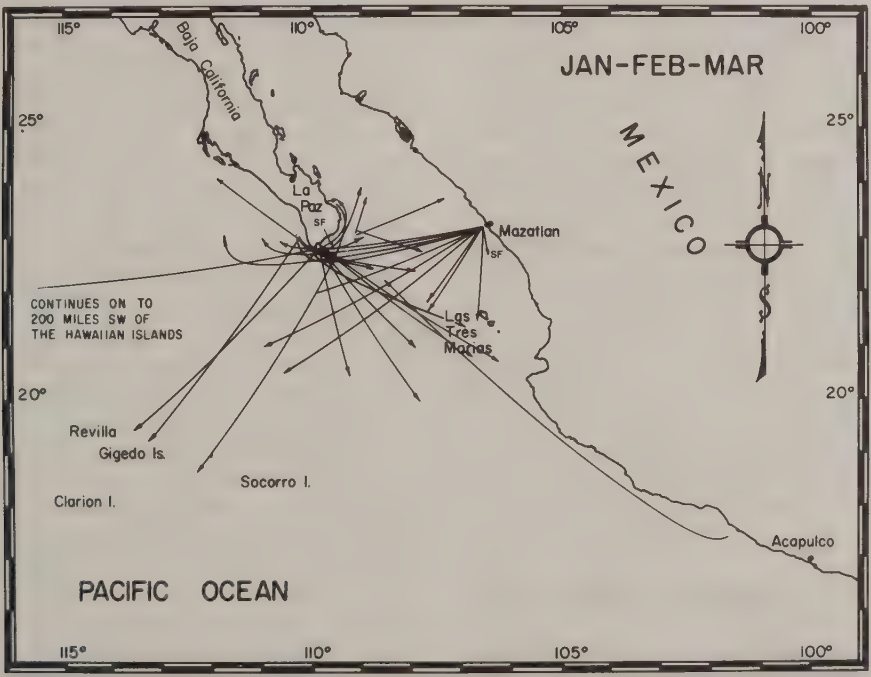


Figure 2.—Movements of billfishes from tagging conducted during the months of January, February, and March. Striped marlin unless otherwise noted as SF (sailfish).

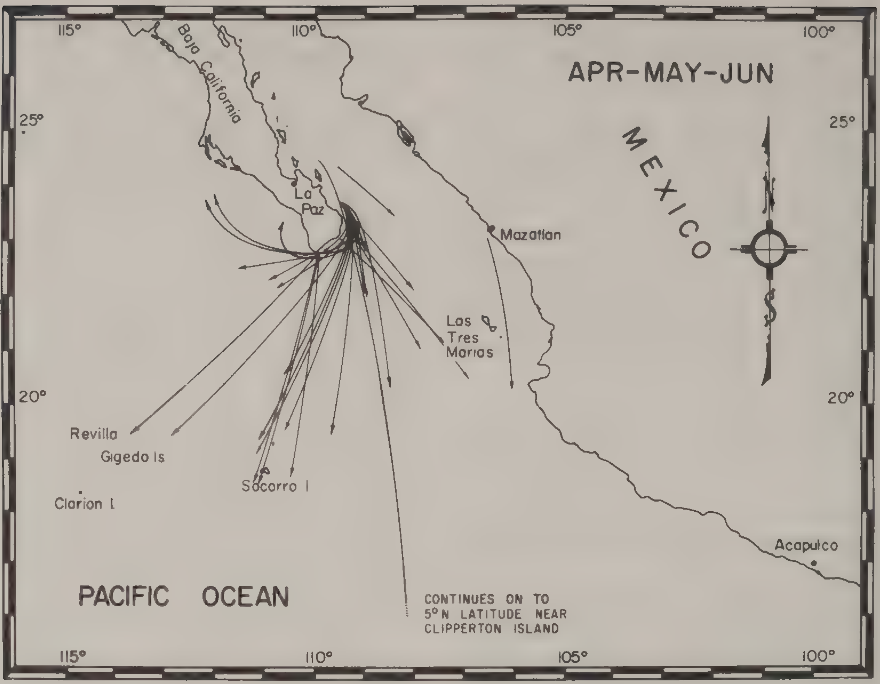
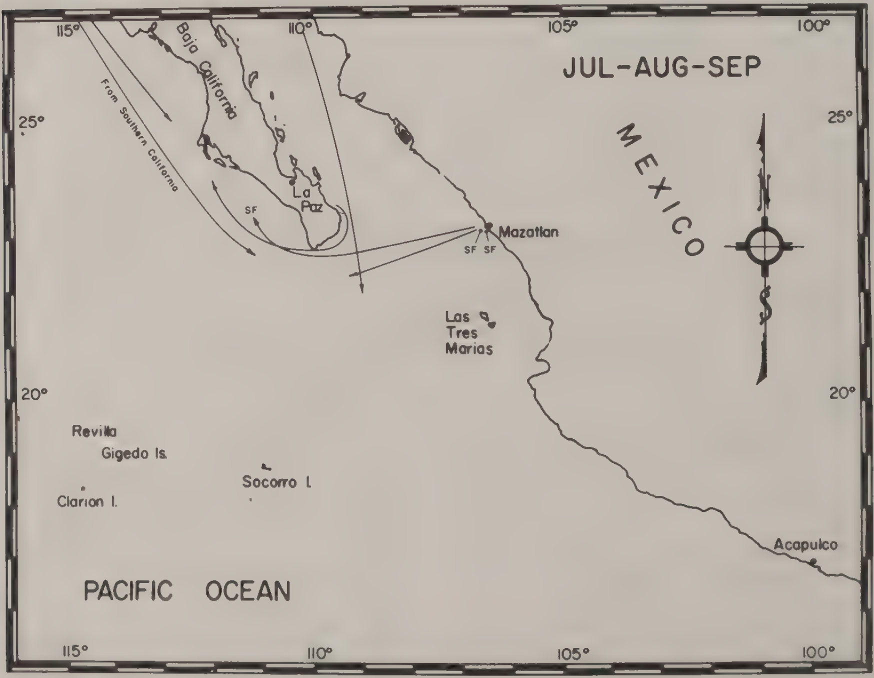

115°
Baja California
110°
105°
100°
APR-MAY-JUN
25°
25°
MEXICO
N
S
La Paz
Mazatlan
Las Tres Marias
20°
20°
Revilla Gigedo Is
Socorro I
Clarion I.
Acapulco
PACIFIC OCEAN
CONTINUES ON TO 5°N LATITUDE NEAR CLIPPERTON ISLAND
115°
110°
105°
100°

Figure 3.—Movements of striped marlin from tagging conducted during the months of April, May, and June.


115°
Baja California
110°
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100°
JUL-AUG-SEP
25°
25°
From Southern California
MEXICO
N
S
La Paz
SF
Mazatlan
SF SF
Las Tres Marias
20°
20°
Revilla Gigedo Is.
Socorro I.
Clarion I.
Acapulco
PACIFIC OCEAN
115°
110°
105°
100°

Figure 4.—Movements of billfishes from tagging conducted during the months of July, August, and September. Striped marlin unless otherwise noted as SF (sailfish).

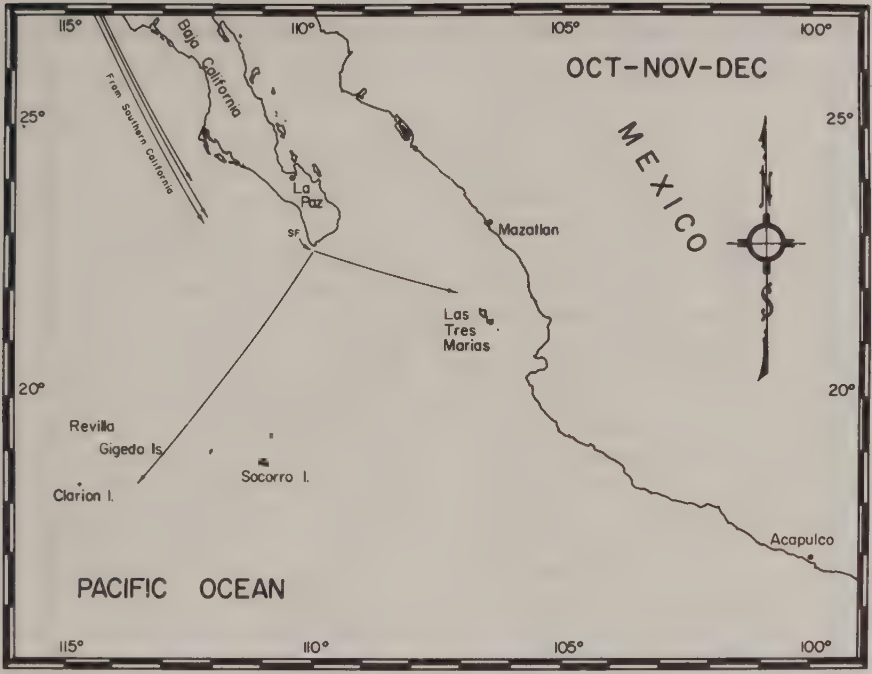

Figure 5.—Movements of billfishes from tagging conducted during the months of October, November, and December. Striped marlin unless otherwise noted as SF (sailfish).

along the east side of the tip of Baja California have shown some movement about the tip to the west and northwest. The longest southward migration of any tagged striped marlin was recorded during this period; the marlin's total straight line migration was 1,153 nautical miles from near the tip of Baja California to near Clipperton Island in 71 days (reference, Fig. 3).

July, August, September.—A reduction in tagging effort due to fewer sportfishermen traveling to the tip of Baja California and the west coast of Mexico during the warm season is reflected in the numbers of billfishes tagged and later recovered. Short distance sailfish recoveries were made near Mazatlán. A sailfish, tagged during this period off Mazatlán, was recovered northwest of the tip of Baja California, a distance of 250 nautical miles, after 457 days. This sailfish recovery was the greatest in distance and time (reference, Fig. 4).

Striped marlin fishing becomes productive off southern California in late August and two recoveries were made off the southern west coast of Baja California of striped marlin tagged off southern California in September. One recovery was made of a striped marlin tagged off Guaymas, Mexico, which is located on the east coast in the upper Gulf of California, and recaptured south of the tip of Baja California 17 days later.

October, November, December.—This is a period of reduced tagging throughout all eastern Pacific sportfishing areas. A limited amount of tagging off southern California has yielded returns, one being the second longest return recorded, 2,090 nautical miles to the southwest in 179 days. Three recoveries of striped marlin tagged off southern California were recovered northwest of the tip of Baja California 1 to 4 months later (reference, Fig. 5).

As in any conventional tagging or marking program only two points in the migration are known —the location of tagging and the tag recovery point. The geographical migratory course of the billfish between these two points is unknown.

Southwestern Pacific

Through the cooperation of anglers fishing for black marlin near Cairns, Queensland, Australia, recoveries of two tagged black marlin have been recorded (Fig. 6). One was recovered by a Japanese

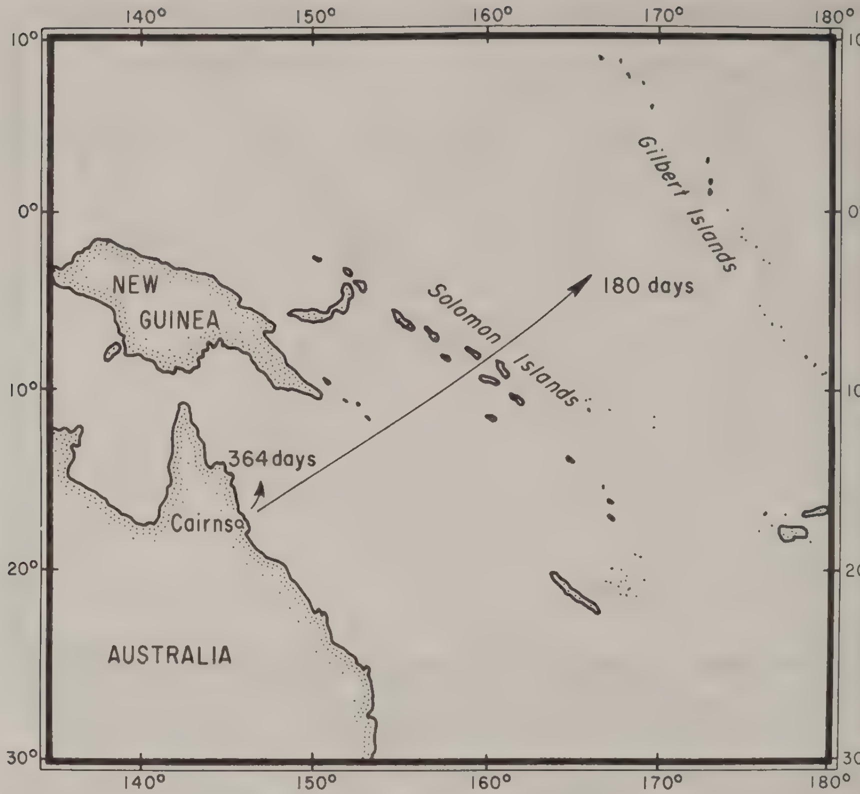
140°
150°
160°
170°
180°
10°
0°
10°
20°
30°
Gilbert Islands
180 days
Solomon Islands
NEW GUINEA
364 days
Cairns
AUSTRALIA

Figure 6.—Movements of black marlin tagged off Queensland, Australia.

longliner 364 days after tagging about 90 nautical miles north from the point of tagging near Hope Reef, Queensland, Australia. The second was recovered 180 days after tagging by a Taiwanese longliner 1,440 nautical miles northeast of the tagging site at Escape Reef, Queensland, Australia.

MIGRATION RATES AND TIMES

The speed of migration of striped marlin, expressed in nautical miles per day projected on a straight line/time basis, varies considerably between local and distant water recoveries (Fig. 7). For billfishes tagged off the Baja California/Mazatlán area the average time at liberty was 94 days. An average distance of 176 nautical miles traveled equals 1.9 nautical miles per day. Striped marlin tagged off southern California recovered near the tip of Baja California had an average release time of 52 days and a migration rate of 12.3 nautical miles per day. Other long distance migration rates are as follows; southern California to southwest of the Hawaiian Islands, 26.0 nautical

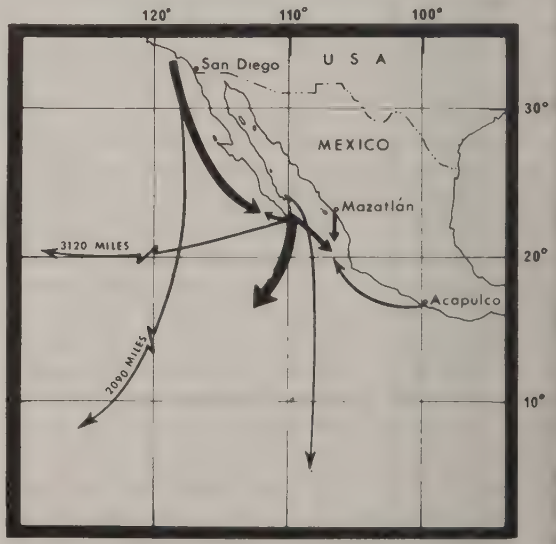
120°
110°
100°
San Diego
U S A
30°
MEXICO
Mazatlán
20°
3120 MILES
Acapulco
2000 MILES
10°

Figure 7.—General migration patterns of striped marlin tagged off southern California and Mexico.

miles per day; tip of Baja California to ⅔ the distance to the Hawaiian Islands, 11.7 nautical miles per day; tip of Baja California to near Clipperton Island, 16.3 nautical miles per day.

For all striped marlin recoveries having accurate records, the average days out is 89; the average migration 281 nautical miles, and average distance per day out, 3.16 nautical miles.

For the limited number of sailfish recaptured the average number of days out was 113, the migration rate was 0.4 nautical miles per day. The longest distance recorded for any sailfish was 250 nautical miles in 457 days out. This was the longest release-recapture time of any billfish tagged in the Pacific.

Two black marlin were recovered, one near the point of tagging in the Coral Sea 364 days after tagging, the other 180 days after tagging, 1,440 nautical miles northeast of Queensland, Australia. This billfish averaged 8 nautical miles per day.

The greatest migration rate in nautical miles per day for any billfish was a short-term recovery of a striped marlin tagged off the tip of Baja California which averaged 31.6 nautical miles per day.

DISCUSSION AND SUMMARY

The concept of utilizing cooperating marine game fish anglers to tag and release billfishes has proven to be a practical approach to the study of billfish migration patterns.

Experience indicates that accurate estimates of weights and lengths of tagged fish cannot be expected.

After tagging, the angler is requested to return the tag card. In 1968 a comparison was made of the number of tags returned with a matching tag card on file, with those that did not have a tag card. This indicated that about 17% of the tag cards were not being returned. As a result, an active campaign to have the angler return the cards was begun.

The number of billfishes tagged annually in the Pacific has steadily increased since 1954, reaching a total of 2,118 in 1971. The annual rate of billfish recoveries rose to above the 0.90% level from 1966 through 1968, dropped to 0.40% in 1969, increased to a peak of 1.16% in 1970, and dropped to a very low 0.13% in 1971. The reason for the sharp decline in recoveries in 1971 cannot be explained. The only change in operation of the National Marine Fisheries Service program was the introduction of the "H" type tag. During the latter half of 1971, 317 "H" tags were used, which equalled only 14.7% of the total tags used by the National Marine Fisheries Service program during 1971.

The recovery rate from FM-67 and FT-1 tags used by the National Marine Fisheries Service and California Department of Fish and Game in the Pacific for striped marlin were comparable. The California Department of Fish and Game program obtained a 0.80% recovery rate using the FT-1 and the National Marine Fisheries Service program obtained a 0.42% recovery rate using the same tag, giving an overall average of 0.66%. The California Department of Fish and Game program restricted its tag distribution to a limited number of experienced anglers fishing from private boats. On an average these anglers were more experienced in tagging billfish than most of the anglers participating in the National Marine Fisheries Service program. The FM-67 tag used for striped marlin shows a greater recovery rate (1.06%) than any of the four types of tags used. The recovery rate of the California Department of Fish and Game FT-1 tag (0.80%) was near that of the FM-67.

The National Marine Fisheries Service program changed to the metal-plastic "H" type tag in mid-1971 because of the recovery record (recovery percent and time out) for white marlin *(Tetrapturus albidus)* and sailfish in the Atlantic Ocean experienced by the Woods Hole Oceanographic Institution program.

Although many factors such as seasons and areas of fishing and economic value of billfishes influence catch rates in the Atlantic and eastern Pacific, a gross comparison of catch rates between the two oceans can be made. Catch and effort data given by the Japanese for Japanese longline operations in the Atlantic and eastern Pacific Oceans and plotted by Gottschalk (1972), show that the total effort in hooks fished was only slightly greater in the Atlantic than in the eastern Pacific for the period 1962 through 1970 (478×10^6 for the Atlantic and 442×10^6 for the eastern Pacific). Charts outlining longlining areas for striped marlin and sailfish in the eastern Pacific by Joseph et al (1973) and for sailfish and white marlin in the Atlantic by Wise and Davis[4] show that these areas are near equal in geographical extent. However, the catch-per-unit-effort (catch/hook) for striped marlin in the eastern Pacific has remained about three times greater over the years than the catch-per-unit-effort for white marlin in the Atlantic, a species that is similar in many respects to the striped marlin. The catch-per-unit-effort for sailfish in the eastern Pacific has averaged about four times the catch rate for the same species in the Atlantic.

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[4] Wise, John P. and Charles W. Davis. 1971. Seasonal distribution of billfish in the Atlantic. Prepared for 22nd Tuna Conference, NMFS, Miami, Fla., 28 p. (mimeo.).

These wide variations in catch rates between the Atlantic and eastern Pacific indicate a possibility of a lower density level or of a much smaller white marlin population, or both, in the Atlantic when compared with striped marlin in the eastern Pacific and sailfish in both oceans. If this is true, given approximately the same fishing effort, a greater percentage of tag recoveries of these species could be expected in the Atlantic.

The recovery rate of striped marlin tagged in the eastern Pacific using the FM-67 plastic tag was slightly less than for the metal tip tags used by the Woods Hole Oceanographic Institution Atlantic program for white marlin (1.06% eastern Pacific, 1.22% Atlantic). The plastic FT-1 tag gave near equal recovery rate results for sailfish in the Atlantic and the eastern Pacific (0.86% eastern Pacific, 0.80% Atlantic). The recovery rate for striped marlin tagged with metal tip "H" tags in the eastern Pacific has been 0.40%.

From the limited amount of data available, no definite conclusions can be reached. However, it appears that the plastic dart tag is as satisfactory as the metal tip dart tag. When the possible differences in population levels and projected recovery rates are considered, the plastic dart tag actually may prove to be superior.

In the northeastern Pacific there have been enough striped marlin tag recoveries to make some observations regarding their migration. Striped marlin usually are available during the first 3 months of the year off Mazatlán, Mexico. Movements of tagged fish from this area are toward the southwest and west, to and beyond the tip of Baja California. In late spring the principal component of the fishery changes to sailfish dominance.

Striped marlin are usually available about the tip of Baja California from late spring through fall. Migrations of tagged fish to the south and some to the west and northwest have been recorded. During late spring and early summer the reproductive activity of striped marlin increases in this area (M. Eldridge and P. Wares,[5] pers. comm.; Kume and Joseph, 1969). Thus the migrations away from the tip of Baja California in a southerly direction may be related to spawning activity of striped marlin in the general vicinity of the Revillagigedo Islands. Some spawning activity has been reported in this area by the Japanese longline fleet during the period late June through October (G. Adachi,[6] pers. comm.). Gonad indices for striped marlin collected in areas of reported spawning have been several times higher than the index found about the tip of Baja California (M. Eldridge,[5] pers. comm.).

Since the amount of longline fishing becomes less as one proceeds north of Magdalena Bay, Baja California, Mexico, the number of returns of striped marlin tagged about the tip and migrating northwest of the Magdalena Bay area would be reduced in proportion to the amount of fishing effort. However, some recoveries have been recorded northwest from the tip of Baja California toward southern California, immediately prior to the movement of striped marlin into the southern California fishery. An increase in catch per effort is noted in this area during the second and third quarters of the year. The southern California sportfishery takes only a small number of striped marlin during late August through October (usually less than 500); the Japanese longline fleet does not operate in this area. Therefore the chance of recovering a striped marlin off southern California is remote. However, from the limited number of striped marlin tagged off southern California and recovered a short time later near the tip of Baja California, indications are that a southerly migration from southern California exists in the fall.

The rates of migration for striped marlin about the tip of Baja California-Mazatlán-Revillagigedo Island area was 1.9 nautical miles per day. Two westward records of long distance migrations from the coast of North America toward Hawaii show rates of 12.3 and 26.0 nautical miles per day. From southern California to near the tip of Baja California, four records show an average migration of 12.3 nautical miles per day. A southward migration from the tip of Baja California to near Clipperton Island was recorded at 16.3 nautical miles per day.

Distant water migrations from southern California and about the tip of Baja California show a much higher migration rate in nautical miles per day when compared with those recaptured near the tip of Baja California, Mexico.

Sailfish recoveries indicate little movement, th longest being 250 nautical miles. Figure 7 represents a summation of the major migrations of striped marlin in the eastern Pacific as determined by the cooperative tagging program. In general, recoveries of striped marlin in the eastern Pacific were short-term (89 days average) and the average migration distance was 281 nautical miles.

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[5] M. Eldridge and P. Wares, National Marine Fisheries Service, Tiburon Fisheries Laboratory, P.O. Box 98, Tiburon, CA 94920.

[6] G. Adachi, P.O. Box 240, Manzanillo, Colima, Mexico.

Certain recommendations can be made regarding the future conduct of cooperative tagging programs in the Pacific for billfishes. These are as follows:

1. Encourage and develop billfish tagging (sport and commercial) throughout the entire Pacific for a better understanding of the migration patterns over the entire area for the major commercial and sport species. In the eastern and central Pacific additional tagging should be conducted off the Hawaiian Islands, southern California, Acapulco, Panama/Ecuador/Peru, Galapagos Islands, Tahiti, and Samoa.
2. Attempt to free-tag (harpoon method) or tag billfishes caught by non-injurious fishing techniques in sufficient numbers to determine hooking mortality.
3. Consider development of improved tags and tagging equipment and experimentally test both the metal tipped and plastic dart tags for histological compatibility and differential shedding by double-tagging billfishes or double-tagging large pelagic species in aquaria tests.
4. If additional tagging programs are to be undertaken in the Pacific in the future the programs should be coordinated between countries with regards to types of tags used, locations and seasons of tagging, publicity, recovery and reward procedures, to achieve the greatest return of information.

ACKNOWLEDGMENTS

Firstly, the success of the tagging program results from the interest and cooperation of the several thousands of billfish anglers who have actively participated by tagging and releasing their billfishes. Secondly, the cooperation of the managers of the various fishing resorts, charter boat skippers, and big game fishing clubs throughout the Pacific and the individuals allied with these organizations for they have been an important factor in the success of the program.

Individually, I would like to recognize Frank Mather III, Horace Witherspoon, William Craig, Gerald Talbot, Wally Giguere, Johanna Alban, and M. Eldridge for their interest and hard work on behalf of the cooperative tagging programs in the Pacific.

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Occurrence of Young Billfishes in the Central Pacific Ocean

WALTER M. MATSUMOTO and THOMAS K. KAZAMA[1]

ABSTRACT

Plankton and other net-caught samples collected on past cruises of the National Marine Fisheries Service, Honolulu Laboratory vessels in Hawaiian and central Pacific equatorial waters were examined for billfish larvae and juveniles. Of the 342 billfish young found in 4,279 net tows, 209 were blue marlin, *Makaira nigricans*, 82 were shortbill spearfish, *Tetrapturus angustirostris*, 2 were sailfish, *Istiophorus platypterus*, 20 were swordfish, *Xiphias gladius*. Twenty-nine larvae were unidentified owing to excessive damage. A preponderance of the catches was obtained from hauls made at the surface during daylight.

In the equatorial central and North Pacific larvae of only three of the six billfish species nominally found in the Pacific were taken. The captures of these larvae (blue marlin, shortbill spearfish, and swordfish) fill the gaps in the known distribution of istiophorids and swordfish, and extend their distribution eastward to the Hawaiian Islands in the North Pacific. The two sailfish larvae were taken in New Hebrides waters in the western South Pacific.

The absence of striped marlin, *Tetrapturus audax*, larvae in Hawaiian waters was significant, since this species comprises nearly 82% of all istiophorids taken on the longline in the Hawaiian fishery. Their absence suggested that the striped marlin in Hawaiian waters probably migrate elsewhere to spawn. If this is true, then the spawning habits of this species differ significantly from those of blue marlin. A similar situation could hold for sailfish also.

In recent years fishery workers have given more attention to the early life history of billfishes, owing to the increasing importance of these fishes in the commercial and sport fishing catches. The billfishes in the Pacific Ocean are represented by two families: Istiophoridae and Xiphiidae. The Istiophoridae includes five species: *Istiophorus platypterus,* sailfish; *Tetrapturus angustirostris,* shortbill spearfish; *T. audax,* striped marlin; *Makaira nigricans,* blue marlin; and *M. indica,* black marlin. The Xiphiidae is represented by a single species, *Xiphias gladius,* swordfish. Larvae of all these species, mainly from the western Pacific, have been identified and reported by Japanese workers.

This study, based on larvae collected on past cruises of the National Marine Fisheries Service, Honolulu Laboratory (HL) vessels in Hawaiian and central Pacific equatorial waters, verifies the identifications reported by Yabe (1953), Yabe et al. (1959), Ueyanagi and Yabe (1959), and Ueyanagi (1959, 1962, 1964), and extends the distribution of larvae of certain billfishes eastward through the central Pacific.

IDENTIFICATION OF LARVAE

The three species of istiophorid larvae in our collection, blue marlin, sailfish, and shortbill spearfish, were easily identified on the basis of black pigmentation (Ueyanagi, 1963) on more than half the length of the lower jaw (sailfish) and on the branchiostegal membranes (shortbill spearfish). Larvae of blue marlin lacked this pigmentation. Since larvae of striped marlin also lack this pigmentation, the separation of blue from striped marlin is most difficult. Ueyanagi (1963) lists two main characters by which he separates the larvae of these two species: (1) the tip of snout either level or below center of eye (striped marlin), and (2) the "anterior edge of orbit projects forward" (blue marlin). The first character is highly subjective and lacks a clear definition of reference points. Even a slight distortion in the body can effect a change in the position of the eye relative to that of the tip of snout. The second

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[1] Southwest Fisheries Center, National Marine Fisheries Service, NOAA, Honolulu, HI 96812.

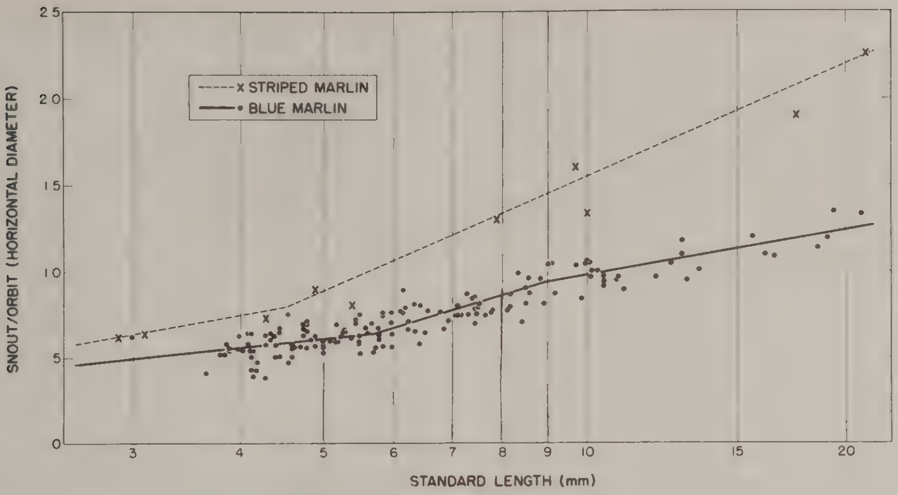

Figure 1.—Snout to orbit (horizontal diameter) ratios of blue and striped marlins. Growth stanzas fitted by Bartlett's best-fit line.

character needs clarification: it is the shape of the orbital crest as well as the extent of protrusion that sets the blue marlin larvae apart from those of striped marlin. In the blue marlin the anterior part of the orbital crest, beginning slightly ahead of the anterior naris, rises sharply and the anteriodorsal part is high and angular. In other istiophorid larvae the orbital crest slopes up and back more gradually (Ueyanagi, 1963, Plate 3).

A more useful character by which larvae of these two species can be separated is the snout to orbit ratio. Ueyanagi (1959) has used this character to show the difference between larvae of sailfish and blue marlin, except that his snout measurement included the distance from the tip of snout to center of eye with the orbit measured vertically. We have used snout length as measured from the tip to the anterior edge of the orbit and the orbit as measured horizontally. Regardless of which snout length or orbit measurement is used, the separation of the curves is similar.

Figure 1 shows the snout to orbit ratios of 138 blue marlin larvae from the central Pacific and 10 striped marlin from the western Pacific (seven measurements from Ueyanagi, 1964 and three measurements from specimens sent to us by Ueyanagi) plotted against standard length. Bartlett's (1949) best-fit lines were drawn through points representing growth stanzas for each species. Despite the small number of points shown for striped marlin, the separation of the species, at least in the larger size range, appears to be valid. Among the smaller stages (below 6 mm), however, the points approach each other close enough to make separation more difficult.

The scatter of points about the curve shown for blue marlin above 6 mm (Fig. 1) and the absence of snout to orbit ratios falling near the curve shown for striped marlin suggest that larvae from the central North Pacific without pigmentation on the posterior half of the lower jaw and branchiostegal membranes are all of blue marlin.

COLLECTION OF SAMPLES AND CATCHES

The samples of billfish larvae were obtained mainly from 1-m plankton net tows taken from vessels of the HL and other organizations from 1950 through 1970, and from 1- × 2-m neuston net tows in 1971. The plankton net was usually towed for 30 min, either horizontally at the surface or obliquely to depths ranging from 40 to 200 m. The neuston net, constructed entirely of 1-mm mesh netting, was used only on one cruise to the western Pacific. Owing to operational difficulties, this net was towed at the regular plankton net speed of 3.7-5.5 km/h for 30 min. Catches by the plankton and neuston nets included juveniles as large as 20 mm. A 12.2-m mouth diameter Cobb pelagic trawl, made of 19.0-mm stretch mesh netting lined with 6.4-mm netting at the cod end, was used on several cruises around Hawaii, in equatorial waters along long. 145°W, and in waters of the Trust Territory of the Pacific Islands from 1967 through 1971, and caught juveniles as large as 55 mm. The midwater trawl was usually towed at night for 3-6 h (Appendix Table 1). The area sampled with towed nets is extensive, covering nearly one-half of the Pacific Ocean (Fig. 2).

A total of 342 billfish larvae and juveniles was obtained from 4,279 net tows of all types. A summary of the catch by type of gear and tow (Table 1) shows that 4,170 tows (97%) were made with the 1-m plankton net, and that of this number 2,850 (68%) were oblique tows. Despite the large ratio of oblique to surface tows (2:1), the catch ratio was just the opposite. The surface tows caught five times as many larvae and juveniles as the oblique tows.

A closer look at the 1-m net tows by depth and time of day (Table 2) shows that most of the larvae were taken in the upper 1-m of water during daylight. The small numbers taken in the oblique tows suggest that these larvae are restricted to the surface, and the small catches in night tows suggest that these larvae migrate downward at night. Both observations are similar to the results obtained by Ueyanagi (1964) in the western Pacific, where he examined 32 day and 31 night plankton net samples from depths of 0, 20, and 40 m. He found that abundance of larvae decreased with depth during the day, and that the day catches at the surface were greater than those at night. His data point out one other aspect which does not appear in our data: that within the upper 40 m of

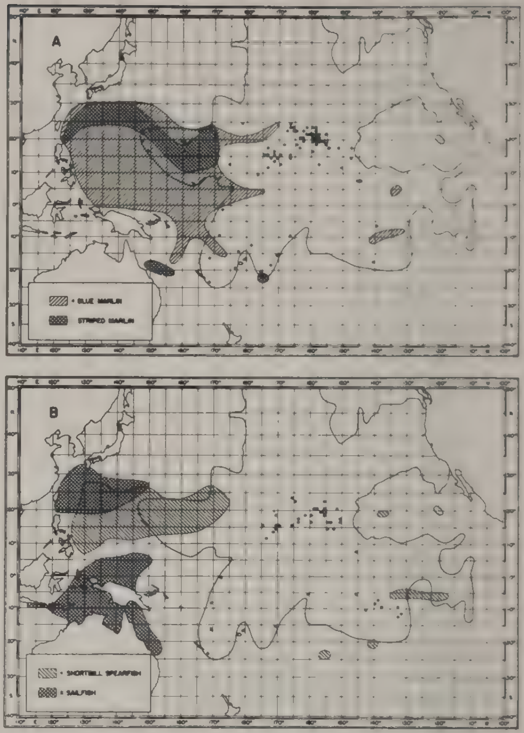

Figure 2.—Localities of captures of young Istiophoridae in the Pacific Ocean. Area sampled by the Honolulu Laboratory indicated by solid line and capture sites by black dots. Localities of captures by Howard and Ueyanagi (1965) shown as shaded areas.

Table 1.—Billfish larvae and juveniles collected by various gear from research vessels of the Southwest Fisheries Center, Honolulu Laboratory in the central Pacific Ocean, 1950-71.

Gear	Type of tow	Number tows	Blue marlin	Short-bill spear-fish	Sail-fish	Sword-fish	Damaged un-identi-fied	Total	Per-cent
1-m plankton net	30-min, surface	1,320	142	68	2	16	22	250	73.1
1-m plankton net	30-min, 40-200m oblique	2,850	25	14	0	4	7	50	14.6
Cobb pelagic trawl	6-h, 20-100m horizontal	92	18	0	0	0	0	18	5.3
1 × 2 m neuston net	30-min, surface	17	24	0	0	0	0	24	7.0
Totals		4,279	209	82	2	20	29	342	100.0
Percent			61.1	24.0	0.6	5.8	8.5	100.0	

Table 2.—Catch rates (catch per 100 tows) of billfish larvae in 1-m plankton net and 1- × 2-m neuston net.

			Species									
	No. of tows		Blue marlin		Short-bill spearfish		Sailfish		Swordfish		All species including unidentified larvae	
Type of tow	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
Surface	201	1,119	50.0	3.7	14.8	3.5	1.0	0.0	2.0	1.1	74.2	8.9
Oblique	1,280	1,570	0.7	1.0	0.4	0.5	0.0	0.0	0.2	0.1	1.5	2.1
Neuston	15	0	160.0	—	0.0	—	0.0	—	0.0	—	160.0	—

water, the catches at night at the three depths sampled were approximately equal.

The neuston net catches (Table 2) provide further information on the vertical distribution of these larvae. The net was normally towed with part of the net above the surface, so that on an average it only sampled the upper 0.5 m of water. The catch per tow was more than three times that of the 1-m net towed fully submerged at the surface. Since the neuston net strained roughly twice the volume of water as the 1-m net, the catch per unit volume of water strained was about 1.5 times that of the 1-m net. The higher catch rate of the neuston net thus suggests that billfish larvae could be concentrated not only in the upper 1-m of water but even closer to the surface.

DISTRIBUTION OF ISTIOPHORID LARVAE

Howard and Ueyanagi (1965) have plotted the occurrence of istiophorid larvae in the Pacific Ocean. Outlines drawn of their plots by species (Fig. 2) show that catches of most species were largely confined to the western Pacific. Our data of larval captures fill the gaps in the distribution given by Howard and Ueyanagi (1965), particularly around the Hawaiian Islands and in the central Pacific south of the equator. The northern limits of distribution of the four species of Istiophoridae in the western North Pacific are notably similar (Fig. 2, panels A and B). The southern limits of distribution for all species cannot be defined, since sampling for the larvae on all cruises east of long. 180° did not extend far enough southward. Judging on the basis of the close relationship between larval distribution and the 24°C surface isotherm (Ueyanagi, 1964; Jones and Kumaran, 1964) and on the configuration of the surface temperature isotherms across the South Pacific (U.S. Hydrographic Office, 1948), it seems that the southern limits of distribution of these larvae should not extend much beyond lat. 25°S.

Blue Marlin

Blue marlin larvae, which comprised 60.8% of all billfish larvae collected by us, occurred in both the North and South Pacific. In the North Pacific they were distributed heavily around the Hawaiian Islands and in waters to the west between lat. 7° and 24°N. This distribution seems to be contiguous with that shown by Howard and Ueyanagi (1965). In the South Pacific the larvae occurred in a band between lat. 0° and 24°S from the New Hebrides through the Tuamotu Archipelago. The western end of this band ties in with the southwestern outline of the distribution of Howard and Ueyanagi (1965). The intervening area (lat. 5°-10°N and long. 140°W-180°) appears to be devoid of blue marlin larvae, but this could be due to inadequate sampling; only a few surface day tows were made there. Sampling especially for billfish larvae would likely change this distributional picture and provide us with better information in the area east of long. 140°W and in equatorial waters westward to long. 180°.

Seasonal Distribution.—Seasonal changes in the distribution of blue marlin larvae were observed only in the Hawaiian Islands area, where enough seasonal sampling was done (Fig. 3). The blue marlin, as well as some other billfishes, spawn throughout the year in warm tropical and subtropical waters. At both the northern and southern fringes of distribution, however, spawning occurs only during the warm seasons (Howard and Ueyanagi, 1965). In the Hawaiian Islands area, the northern fringe of larval blue marlin distribution lies roughly parallel to the surface isotherms (Fig. 3) and moves northeastward and southwestward with the seasons. Thus, in the first quarter the larvae were found far south of the island, but in the second quarter they were abreast of the islands. In the third quarter the edge of larval distribution shifted northward a few degrees of latitude past the islands and moved back to just south of the islands in the fourth quarter. The northward shift of the distribution during the four seasons is about 10° to 11° of latitude.

Ueyanagi (1964) reports that larvae of istiophorid species occur generally in water that is warmer than 24°C. Jones and Kumaran (1964) also show that none of their larvae were taken in waters colder than 24.5°C. Our data (Appendix Table 1) show that although most of the blue marlin larvae were taken in water between 26° and 29°C, the lowest temperature associated with capture was 23.8°C.

Shortbill Spearfish

Larvae of shortbill spearfish comprised 24.3% of all billfish larvae collected by us. Their distributional pattern in the central Pacific is similar to that of blue marlin larvae (Fig. 2). North of the equator the captures were grouped around the Hawaiian Islands in an area bounded by lat. 10° and 23°N and long. 150° and 174°W. The area between long. 174°W and the eastern limit of Howard and Ueyanagi's (1965) data should also contain larvae of this species to show a continuous distribution from the western Pacific to the Hawaiian Islands. Because of inadequate sampling, only three surface day tows and eight oblique tows, no larvae were taken there.

South of the equator, larvae were taken in a banc (lat. 0° to approximately 20°S) extending from the New Hebrides Islands through the Tuamotu Archipelago, similar to that for blue marlin. The gap ir the distribution along the equator, between lat. 7°N and 5°S, may be interpreted in two ways: first, th gap could be due to insufficient samples of surfac day tows; and second, the gap could represent separation of the shortbill spearfish into norther and southern populations. The latter is supporte

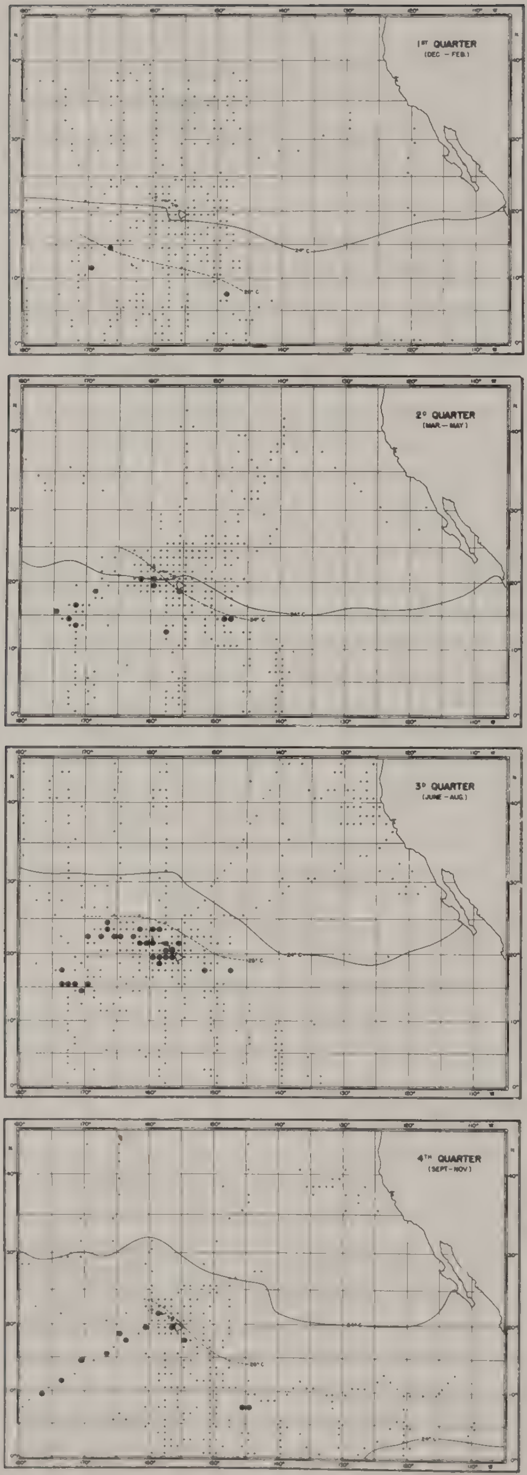

Figure 3.—Localities of captures of young blue marlin b quarters. Solid lines represent mean surface temperatu for last month of quarter. Dashed lines represent surfa temperature at time of sampling. Small open circles re resent sampling with plankton nets in 1° square area; lar solid dots represent capture sites.

by the discontinuous north-south distribution of larvae in the western Pacific, compared with the continuous distribution across the equator of blue marlin larvae.

Seasonal Distribution.—The seasonal occurrence of shortbill spearfish larvae in the Hawaiian Islands (Fig. 4) resembles that of blue marlin in certain respects, the northern edge of distribution being parallel to the chain of islands and the movement across the islands being from southwest to northeast. The differences, though small, are nevertheless evident. In the first quarter shortbill spearfish larvae were found approximately 500 km southwest of the islands, as compared to about 950 km for blue marlin larvae. The northern edge of the larval distribution shifted northeastward to about 320 km past the islands in the second quarter, retreated to the islands in the third quarter, and continued southwestward past the islands in the fourth quarter. This north-south movement of larval shortbill spearfish distribution seemed to precede that of larval blue marlin distribution by a full quarter.

One reason for these differences could be that the shortbill spearfish may be able to spawn in colder water than the blue marlin. The temperature data seem to suggest this. Shortbill spearfish larvae were found in waters with temperatures as low as 22.3°C, with most catches having been made in 25° to 26°C water. Both minimum and best catch temperatures for shortbill spearfish larvae were at least 1°C lower than for blue marlin larvae.

DISTRIBUTION OF XIPHIID LARVAE

Larvae of the Xiphiidae, the second of two families that make up the billfishes, were taken only occasionally. Only 20 specimens ranging in sizes from 5.8 to 23.0 mm were found in plankton samples taken from 1950 through 1971 (Table 1 and Appendix Table 2).

Larval and juvenile stages of swordfish from the Atlantic and Pacific Oceans have been described by a number of workers (Arata, 1954; Nakamura et al.,

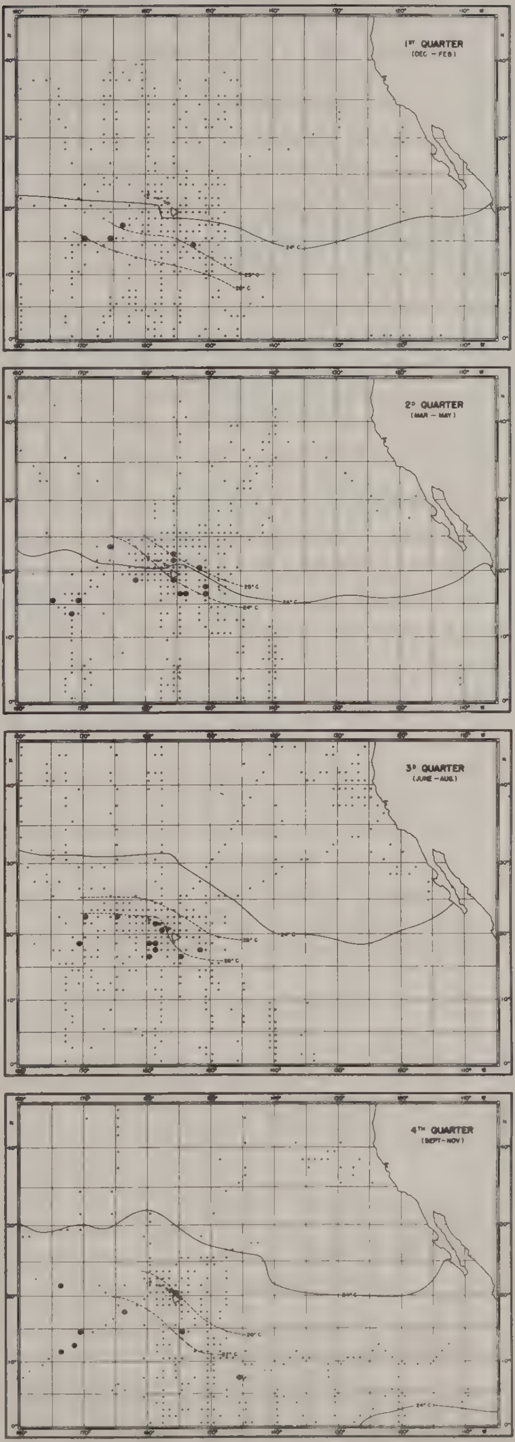

Figure 4.—Localities of captures of young shortbill spearfish by quarters. Solid lines represent mean surface temperature for last month of quarter. Dashed lines represent surface temperature at time of sampling. Small dots represent sampling with plankton nets in 1° square area; large dots represent capture sites.

1954; Yabe, 1951; and Yabe et al., 1959). The swordfish larvae are easily recognized by their long snouts and heavily pigmented elongate bodies. They have a prominent supraorbital crest similar to that of the marlins, but lack the enlarged posttemporal and preopercular spines. Larvae above 8.0 mm are even more distinctive; they have one or more rows of spinous scales on each side of the dorsal and anal fins, with those along the latter continuing forward to the level of the pectoral fin.

Although the important fishing areas for this species are mainly in temperate waters, the larvae and juveniles are found largely in tropical and subtropical waters throughout most of the Pacific. Figure 5 shows the locations of captures of swordfish larvae and juveniles below 80.0 mm recorded to date and those taken by HL ships. A similar plot of captures, exclusive of those taken by HL, was published by Jones and Kumaran (1964). (One capture site at lat. 23°N, long. 174°W is plotted erroneously. This should have been in the southern hemisphere.) Our samples extend the distribution of young swordfish to waters east of the Hawaiian Islands in the North Pacific, and partially fill in the gap between long. 132° and 172°W in the equatorial and South Pacific. The overall distribution, which extends roughly two-thirds the breadth of the Pacific, is similar to that of blue marlin larvae.

Although captures were spotty throughout the western and central Pacific, there were enough to show differences in spawning time in the various parts of the Pacific. The probable month of spawning (Fig. 5) was calculated for each individual, using the growth estimate of 0.6 mm per day derived by Arata (1954). According to these calculations spawning occurred in spring and summer (March through July) in the central North Pacific and in spring (September through December) in the western South Pacific south of lat. 10°S. In equatorial waters between lat. 10°N and 10°S, spawning occurred in all months of the year. Spawning also seemed to begin and end 1 or 2 mo earlier in the western Pacific in the Philippine-Formosa area, as compared with the Hawaiian Islands area. This is understandable when we consider: (1) that post-larval swordfish are usually taken in the Atlantic in waters having surface temperatures above 23.5°C (Taning, 1955), (2) that in the western Pacific this isotherm lies between Taiwan and the Philippine Islands as early as February, and (3) that in the central Pacific along the same latitude, the 23.5°C isotherm passes northward through the Hawaiian Islands in March or April, a difference of 1 to 2 mo.

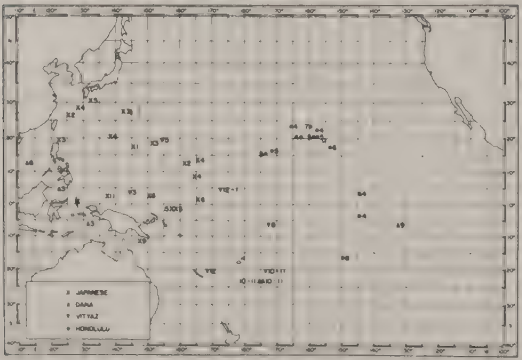

Figure 5.—Localities of captures of young swordfish <80 mm SL in the Pacific. (The numerals next to each capture site denote estimated month of spawning.)

Table 3.—Summary of young swordfish *(Xiphias gladius)* taken in plankton net tows in the Atlantic and Pacific Oceans.

Source[1]	No. of larvae <10 mm	No. of juveniles 10-80 mm	Total
Yabe (1951)	0	1	1
Arata (1954)	4	19	23
Yabe et al. (1959)	5	15	20
Sun Tsi-Gen (1960)	0	17	17
Honolulu Laboratory	14	6	20
Total	23	58	81
Percent	28.4	71.6	100

[1] Tåning (1955) examined 60 larvae of which 53 were <20 mm; no breakdown of larvae <10 mm available.

A unique aspect about the captures of swordfish young is that of the small numbers taken in plankton nets, only 28.4% were larvae smaller than 10 mm (Table 3). Among other pelagic fishes, such as spearfishes, tunas, mackerels, etc., most of the larvae caught in plankton nets are below 10 mm. Perhaps the proportion of larvae caught is reduced inordinately by the disproportionate catches of juveniles. Among other fishes, particularly tunas and mackerels, juveniles above 10 mm are rarely caught, except in much larger gear such as midwater trawls. The large percentage of juveniles up to 80-mm long taken in plankton nets suggests that the swordfish young either do not react to the net quickly enough to avoid it or are exceptionally poor swimmers at this stage of development.

Also noteworthy is the apparent brevity of the spawning season in the northern and southern edges of distribution. Although spawning is indicated for most months of the year in the vicinity of the equator, it extended for only 4 mo, April to July, in the areas above lat. 20°N. By contrast, blue marlin and shortbill spearfish spawning extended over 5 and 6 mo, May through September and May through October, respectively, in Hawaiian waters.

The captures of swordfish larvae off Hawaii also provided new information on the lowest temperatures in which this species spawn. Two larvae (9.6 and 9.8 mm) were taken at long. 157°W in 23.3° and 23.6°C water, well below the lowest temperature previously recorded in the Pacific and comparable to the 23.5°C recorded from the southwestern Atlantic by Tåning (1955).

DISCUSSION

A comparison of the species composition of billfishes taken on the longline and the young taken in plankton nets in Hawaiian waters leads to interesting speculations concerning the spawning behavior of certain istiophorids. For example, the striped marlin is the predominant species taken commercially, in terms of both number and weight of fish caught. An average of 5,685 striped marlin, which make up 81.6% of all istiophorids caught on the longline, were taken annually from 1966 to 1970. Yet, no larva of this species has been recognized from our samples. Alternatively, blue marlin and shortbill spearfish comprise only 9.8% and 3.4%, respectively, of the istiophorids taken on the longline, but they make up the entire catch of young taken in these waters. Larvae of sailfish and black marlin also have not been recognized in our catches. These two species combined represent only 4.5% of the istiophorids taken on the longline.

The absence of striped marlin larvae in Hawaiian waters is probably due to absence of spawners. Length-frequency data (Royce, 1957; Howard and Ueyanagi, 1965) show that very young fish less than 150-cm modal length (11 kg[2]) first appear in the fishery in the fall and remain there continuously through two successive seasons, by which time they have attained a modal length of 220 cm (45 kg). No one has yet studied the size of striped marlin at initial spawning but it is suspected that fish in the last modal group may have reached sexual maturity, since fish of similar sizes were found with ripe gonads in the western Pacific between lat. 15° and 30°N (Howard and Ueyanagi, 1965). A more striking phenomenon about the striped marlin fishery in Hawaii is that fish in the last modal group disappear in July and do not reappear as a group in the fishery. To be sure striped marlin larger than this modal size have been taken there but only in small quantities comprising less than 1% of the total monthly catches.

On the basis of the discussion above and the occurrence of both larvae and adults with ripe gonads only in the area between lat. 15° and 30°N, west of long. 170°E (Howard and Ueyanagi, 1965) in the North Pacific, it is logical to assume that the striped marlin in Hawaiian waters leave the islands to spawn, most likely in the western North Pacific. If this is so, the spawning habit of this species differs significantly from that of blue marlin, which spawn almost continuously between lat. 30°N and 25°S in the western and central Pacific.

The absence of sailfish larvae in the central Pacific, except in the western South Pacific (New Hebrides Islands), suggests that this species also may spawn in selective areas.

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[2] Conversion of weight (lb) to estimated length (cm) through courtesy of R.A. Skillman, Honolulu Laboratory.

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Appendix Table [illegible].--Number of catches of istiophorid larvae and juveniles by the Southwest Fisheries Center, Honolulu Laboratory from [illegible] to [illegible].

Gear	Type of tow	Depth of tow	Vessel, cruise, station or sample	Date	Time	Position		Duration of tow		Volume of water strained	Surface temperature	Surface salinity	Larval and juvenile catches[2]						Size range
						Latitude	Longitude						SF	Bl	SB	BB	[illegible]	Total	
								Hr.	Min.	m³	°C	‰							mm
1-m plankton net	Horizontal	0	S-4-24-1	5/14/50	0820	22°45' N	155°49' W	-	-	1255	22.9	-	-	-	1	-	-	1	5.0
Do.	do.	0	S-4-23-1	5/14/50	1852	22°40' N	157°10' W	-	-	2192	23.3	-	-	-	-	1	-	1	ca. 9.6
Do.	do.	0	S-4-4-1	5/17/50	1640	20°14' N	161°08' W	-	-	2125	24.2	-	-	1	-	-	-	1	4.5
Do.	do.	0	S-4-6-1	5/18/50	1048	19°25' N	159°50' W	-	-	2272	24.8	-	-	1	-	-	-	1	4.3
Do.	do.	0	S-4-7-1	5/18/50	1835	20°14' N	159°50' W	-	-	2967	24.9	-	-	1	-	-	-	1	5.0
Do.	do.	0	S-4-15-1	5/21/50	1610	20°13' N	158°30' W	-	-	2950	24.5	-	-	-	-	2	-	2	10.5, ca. 19.3
Do.	do.	0	S-4-20-1	5/23/50	0911	20°14' N	157°04' W	-	-	3346	23.6	-	-	-	-	1	-	1	6.6
Do.	do.	0	S-4-25-1	5/24/50	1333	21°54' N	155°48' W	-	-	2645	22.3	-	-	-	1	-	-	1	4.5
Do.	do.	0	S-4-28-1	5/25/50	1740	18°34' N	155°48' W	-	-	3169	23.8	-	-	1	-	-	-	1	4.6
Do.	do.	0	S-6-14-1	8/18/50	1720	20°50' N	158°32' W	-	-	2287	-	-	-	3	-	-	1	4	3.9-7.1
Do.	do.	0	S-6-16-1	8/19/50	0750	19°24' N	158°23' W	-	-	3380	26.6	-	-	4	-	-	-	4	4.3-5.3
Do.	do.	0	S-6-17-1	8/19/50	1522	18°30' N	158°29' W	-	-	2240	26.7	-	-	2	1	-	-	3	3.7-3.8
Do.	do.	0	S-6-18-1	8/20/50	0210	18°32' N	157°08' W	-	-	1609	26.2	-	-	-	-	-	1	1	3.4
Do.	do.	0	S-6-19-1	8/20/50	2311	19°31' N	157°10' W	-	-	2728	26.0	-	-	-	-	-	1	1	5.5
Do.	do.	0	S-6-20-1	8/21/50	0815	20°23; N	157°07' W	-	-	2112	26.2	-	-	1	2	-	-	3	3.1-5.2
Do.	do.	0	S-6-21-1	8/21/50	1412	20°56' N	157°10' W	-	-	2767	25.8	-	-	1	-	-	-	1	2.8
Do.	do.	0	S-6-25-1	8/22/50	1500	21°56' N	155°45' W	-	-	2816	25.7	-	-	4	-	-	-	4	4.0-6.0
Do.	do.	0	S-6-22-1	8/23/50	1754	21° 50' N	157°10' W	-	-	2586	25.7	-	-	1	-	-	-	1	6.0
Do.	do.	0	S-6-12-1	8/24/50	1250	22°43' N	158°26' W	-	-	2106	-	-	-	2	-	-	-	2	5.2, 6.3
Do.	do.	0	S-6-11-1	8/25/50	0500	23°27' N	159°46' W	-	-	2374	- -	-	-	2	-	-	-	2	5.1, 6.7
Do.	do.	0	S-6-1-1	8/25/50	1405	23°30' N	161°06' W	-	-	2047	26.0	-	-	2	-	-	-	2	5.1, 5.5
Do.	do.	0	S-6-3-1	8/26/50	1042	21°10' N	161°03' W	-	-	2150	26.7	-	-	2	-	-	-	2	4.5, 5.5
Do.	do.	0	S-6-4-1	8/26/50	1750	20°20' N	161°05' W	-	-	2251	26.7	-	-	-	-	-	4	4	4.6-5.6
Do.	do.	0	S-6-6-1	8/27/50	0950	19°26' N	159°50' W	-	-	2393	26.0	-	-	3	-	-	-	3	4.7-6.7
Do.	do.	0	S-6-9-1	8/28/50	1350	21°05' N	159°50' W	-	-	2456	26.0	-	-	3	-	-	-	3	5.4-10.2
1-m plankton net	horizontal	0	S-38-59-3	3/3/57	2035	17°48' S	135°06' W	-	-	1176		-	-	1	-	-	-	1	ca. 3.9
Do.	do.	0	S-38-62-3	3/17/57	2147	5°01' S	144°57' W	-	-	1778	28.7	35.37	-	-	1	-	-	1	3.3
Do.	do.	0	S-39-21-1	5/9/57	2010	23°03' N	165°23' W	-	-	-	25.1	35.21	-	-	6	5	-	11	SB 3.8-5.2, BB ca. 7.3-15.8
Do.	do.	0	S-39-28-1	5/15/57	2010	20°03' N	162°04' W	-	-	-	25.1	34.96	-	-	-	3	-	3	ca. 6.5-20.0
Do.	do.	0	G-30-14	8/23/56	0747	9°22' S	132°10' W	-	-	1670	25.2	35.41	-	-	1	-	-	1	6.5
Do.	do.	0	G-30-15-1	8/23/56	1954	9°48' S	132°07' W	-	-	1672	25.4	35.41	-	-	1	-	-	1	ca. 5.5
Do.	do.	0	G-30-17-4	8/24/56	2035	11°10' S	131°56' W	-	-	1776	25.0	35.71	-	-	1	-	-	1	4.2
Do.	do.	0	G-30-18	8/25/56	0750	12°12' S	132°05' W	-	-	1891	24.7	35.79	-	-	2	-	-	2	5.2, 6.0
Do.	do.	0	G-30-29-1	8/30/56	2000	9°22' S	137°01' W	-	-	1505	25.7	35.66	-	-	1	-	-	1	ca. 4.1
Do.	do.	0	G-30-31	9/1/56	0756	7°32' S	138°54' W	-	-	2021	25.6	35.64	-	-	7	-	-	7	ca. 5.2-7.2
Do.	do.	0	G-30-33	9/2/56	0750	8°50' S	139°08' W	-	-	1380	25.7	35.84	-	-	1	-	-	1	8.6
Do.	do.	0	G-45-29-2	7/29/59	1958	16°48' N	154°38' W	-	-	1284	25.9	-	-	-	1	-	-	1	ca. 4.3
Do.	do.	0	G-48-61	7/24/60	1955	16°04' N	160°08' E	-	-	-	28.9	-	-	1	-	-	-	1	5.1
Do.	do.	0	G-48-63	7/25/60	2000	18°16' N	160°11' E	-	-	-	28.9	-	-	2	-	-	1	3	4.0-4.5
Do.	do.	0	G-48-65	7/26/60	2000	19°56' N	160°09' E	-	-	-	28.8	-	-	2	-	-	-	2	4.3, 5.2
Do.	do.	0	G-53-17-1	7/8/61	1120	18°46' N	158°46' W	-	-	1675	26.0	34.68	-	-	1	-	-	1	7.6
Do.	do.	0	G-53-19-1	7/9/61	1107	16°01' N	159°55' W	-	-	2374	25.8	34.54	-	1	1	-	-	2	Bl. 6.0, SB 8.7
Do.	do.	0	G-53-27-1	7/12/61	1005	22°07' N	164°37' W	-	-	1803	26.2	35.05	-	-	1	-	-	1	10.1
Do.	do.	0	G-53-32-1	7/15/61	1000	22°58' N	169°21' W	-	-	2082	26.5	34.97	-	2	1	-	-	3	4.1-4.9
Do.	do.	0	G-53-34-1	7/16/61	1000	19°42' N	169°41' W	-	-	2097	26.9	34.84	-	-	-	-	1	1	8.0

Appendix Table 1.--Record of catches of istiophorid larvae and juveniles by the Southwest Fisheries Center, Honolulu Laboratory from 1950 to 1971.--Continued.

Gear	Type of tow	Depth of tow	Vessel[1]/ cruise/ station sample	Date	Time	Position		Duration of tow		Volume of water strained	Surface temperature	Surface salinity	Larval and juvenile catches[2]						Size range
						Latitude	Longitude	Hr.	Min.	m³	° C	°/..	SF	BL	SB	BB	UN	Total	mm
1-m plankton net	horizontal	0	G-53-42-1	7/22/61	1009	22°29' N	167°05' W	-	-	1980	26.5	35.00	-	1	-	-	-	1	17.2
Do.	do.	0	G-53-46-1	7/24/61	1103	22°33' N	162°04' W	-	-	1865	26.4	34.83	-	2	-	-	-	2	5.5, 12.6
Do.	do.	0	G-53-48-2	7/25/61	0207	20°25' N	162°15' W	-	-	1691	26.9	34.84	-	1	-	-	-	1	4.4
Do.	do.	0	G-53-49-1	7/25/61	1104	19°02' N	162°07' W	-	-	2061	27.0	34.73	-	1	-	-	-	1	9.0
Do.	do.	0	G-53-52-2	7/27/61	0209	18°57' N	159°59' W	-	-	2213	26.3	34.67	-	-	1	-	1	2	4.0-4.4
Do.	do.	0	G-53-54-2	7/27/61	2105	21°50' N	159°54' W	-	-	1851	26.5	-	-	-	-	-	1	1	4.9
Do.	do.	0	G-54-4-1	10/ 1 /61	2007	14°14' N	154°32' W	-	-	1770	26.9	34.42	-	-	1	-	-	1	6.0
Do.	do.	0	G-55-5-1	1/17/62	1000	17°00' N	163°00' W	-	-	-	25.0	-	-	-	1	-	-	1	4.3
Do.	do.	0	G-55-7-1	1/18/62	0558	15°06' N	165°15' W	-	-	-	25.0	-	-	-	3	-	-	3	4.5-6.4
Do.	do.	0	G-55-8-1	1/18/62	1713	14°03' N	166°39' W	-	-	-	26.0	-	-	1	-	-	-	1	6.2
Do.	do.	0	G-55-11-1	1/19/62	1544	12°05' N	169°01' W	-	-	-	26.8	-	-	2	-	-	-	2	8.9, 9.9
Do.	do.	0	G-55-12-2	1/19/62	1903	11°47' N	169°19' W	-	-	-	27.1	-	-	-	-	-	1	1	3.8
Do.	do.	0	G-55-26-2	1/29/62	1356	9°40' S	171°38' E	-	-	-	29.2	-	-	5	-	-	1	6	3.5-10.2
Do.	do.	0	G-55-34-2	2/1/62	0758	15°36' S	169°52' E	-	-	-	28.7	-	-	-	-	-	1	1	3.8
Do.	do.	0	G-55-35-2	2/1/62	1355	16°16' S	169°28' E	-	-	-	28.5	-	2	-	-	-	-	2	4.6, 4.7
Do.	do.	0	G-55-36-2	2/1/62	2015	16°40' S	168°57' E	-	-	-	28.5	-	-	2	-	-	-	2	3.8
Do.	do.	0	G-55-53-1	2/15/62	0805	19°37' S	176°43' E	-	-	-	27.2	-	-	9	-	-	1	10	4.0-6.5
Do.	do.	0	G-55-62-1	2/23/62	0810	14°59' S	177°13' E	-	-	-	28.7	-	-	2	-	-	1	3	3.8-5.3
Do.	do.	0	G-55-85-1	3/1/62	2100	18°48' S	176°31' W	-	-	-	28.6	-	-	-	-	-	1	1	4.3
Do.	do.	0	G-55-86-2	3/2/62	0809	20°21' S	175°42' W	-	-	-	27.7	-	-	1	-	-	-	1	10.4
Do.	do.	0	G-55-102-1	3/13/62	1957	15°05' S	170°48' W	-	-	-	28.3	-	-	2	1	-	-	3	4.3-4.5
Do.	do.	0	G-55-111-2	3/22/62	0803	9°52' S	166°16' W	-	-	-	28.8	--	-	1	-	-	-	1	4.0
Do.	do.	0	G-58-49	7/15/62	1342	23°27' N	164°51' W	-	-	2080	26.5	34.94	-	1	-	-	-	1	8.4
Do.	do.	0	G-58-53	7/16/62	0100	24°17' N	166°15' W	-	-	2427	25.6	35.06	-	3	-	-	-	3	3.8-4.7
Do.	do.	0	G-58-60	7/17/62	0100	22°55' N	165°41' W	-	-	1644	26.5	34.93	-	1	-	-	-	1	3.9
Do.	do.	0	G-58-63	7/17/62	1300	22°10' N	164°12' W	-	-	1212	26.5	34.98	-	1	-	-	-	1	10.3
Do.	do.	0	G-69-1-1	10/8/63	0827	19°44' N	160°15' W	-	-	-	27.1	-	-	1	-	-	-	1	ca. 13.9
Do.	do.	0	G-69-3-1	10/9/63	0755	17°39' N	163°33' W	-	-	-	27.2	-	-	1	2	-	-	3	BL 9.4, SB 4.2, 18.7
Do.	do.	0	G-69-5-1	10/10/63	0754	15°24' N	166°55' W	-	-	-	27.3	-	-	7	-	-	-	7	4.3-6.0
Do.	do.	0	G-69-7-1	10/11/63	0757	14°32' N	170°22' W	-	-	-	27.8	-	-	2	1	-	-	3	7.6-11.5
Do.	do.	0	G-69-9-1	10/12/63	0757	11°30' N	173°35' W	-	-	-	28.2	-	-	11	2	-	-	13	5.9-13.3
Do.	do.	0	G-69-11-1	10/13/63	0758	9°11' N	176°48' W	-	-	-	28.2	-	-	2	-	-	-	2	3.8, 4.3
Do.	do.	0	G-69-27-1	10/22/63	0156	0°53' S	172°18' W	-	-	-	-	-	-	-	1	-	-	1	3.4
Do.	do.	0	G-69-28-1	10/22/63	0757	1°47' S	172°05' W	-	-	-	-	-	-	4	-	-	3	7	3.6-10.0
Do.	do.	0	G-69-36-1	10/24/63	2000	8°10' S	169°27' E	-	-	-	-	-	-	-	1	-		1	4.4
Do.	do.	0	G-69-75-1	11/22/63	1357	12°37' S	178°12' W	-	-	-	-	-	-	6	-	-	-	6	7.4-10.8
Do.	do.	0	E-3-42	3/8/64	1930	15°32' N	170°32' W	-	-	1920	-	-	-	2	-	-	-	2	6.0, ca. 6.4
Do.	do.	0	E-3-86	3/13/64	1939	16°50' N	172°03' W	-	-	3169	-	-	-	-	-	-	1	1	ca. 4.2
Do.	do.	0	E-5-16	5/9/64	1815	13°20' N	171°02' W	-	-	1657	-	-	-	4	2	-	-	6	4.9-8.6
Do.	do.	0	E-5-36	5/11/64	1815	14°24' N	172°38' W	-	-	1163	-	-	-	1	-	-	-	1	10.3
Do.	do.	0	E-5-53	5/13/64	1817	15°01' N	174°14' W	-	-	1516	-	-	-	-	1	-	-	1	9.2
Do.	do.	0	E-5-59	5/14/64	1815	16°52' N	171°19' W	-	-	1785	-	-	-	2	-	1	-	3	BL 3.9-ca. 6.0, BB 8.3
Do.	do.	0	E-6-17	6/8/64	1926	15°34' N	169°14' W	-	-	1063	-	-	-	3	-	-	-	3	ca. 7.0-7.8
Do.	do.	0	E-6-37	6/10/64	1923	14°17' N	170°13' W	-	-	1294	-	-	-	1	-	-	-	1	5.9
Do.	do.	0	E-6-61	6/12/64	1927	15°03' N	171°49' W	-	-	1271	-	-	-	5	-	-	1	6	3.6-7.7

Appendix Table 1.--Record of catches of istiophorid larvae and juveniles by the Southwest Fisheries Center, Honolulu Laboratory from 1950 to 1971.--Continued.

Gear	Type of tow	Depth of tow	Vessel[1]/ cruise station sample	Date	Time	Position		Duration of tow		Volume of water strained	Surface temperature	Surface salinity	Larval and juvenile catches[2]						Size range
						Latitude	Longitude	Hr.	Min.	m³	° C	°/..	SF	BL	SB	BB	UN	Total	mm
1-m plankton net	horizontal	0	E-6-80	6/14/64	1954	15°53' N	173°27' W	-	-	1455	-	-	-	5	-	1	-	6	BL 5.5-8.6, BB 23.0
Do.	do.	0	E-6-84	6/15/64	1922	18°27' N	170°53' W	-	-	-	-	-	-	-	1	-	-	1	4.9
Do.	do.	0	C-2-13	3/29/64	2003	14°37 ' N	147°58' W	-	-	678?	24.0	34.48	-	1	-	-	-	1	5.2
Do.	do.	0	C-3-13	4/27/64	2020	14°00' N	147°55' W	-	-	1839	24.8	34.52	-	1	-	-	-	1	6.5
Do.	do.	0	C-4-9	5/25/64	2003	20°28' N	151°04' W	-	-	1413	22.9	35.09	-	-	1	-	-	1	24.2
Do.	do.	0	C-4-10	5/26/64	2002	16°29' N	150°58' W	-	-	1588	24.2	34.53	-	-	1	-	-	1	3.8
Do.	do.	0	C-6-10	7/22/64	2000	17°18' N	151°01' W	-	-	2192	25.8	34.78	-	1	1	-	-	2	BL 6.0, SB 3.8
Do.	do.	0	C-6-14	7/26/64	2005	17°03' N	147°58' W	-	-	1515	26.0	34.46	-	1	-	-	-	1	5.8
Do.	do.	0	C-15-6	4/16/65	2000	16°10' N	154°00' W	-	-	2060	25.6	34.32	-	-	4	-	-	4	4.0-4.4
Do.	do.	0	C-15-10	4/20/65	2004	17°07' N	150°59' W	-	-	2573	24.8	34.42	-	-	2	-	-	2	4.6, ca. 4.8
Do.	do.	0	C-16-3	5/27/65	2007	12°58' N	157°04' W	-	-	1488	26.1	-	-	1	-	-	-	1	5.0
Do.	do.	0	C-46-23-3	10/21/69	0100	7°26' N	144°43' W	-	-	1333	28.4	33.84	-	1	-	-	-	1	5.2
Do.	do.	0	C-46-27-1	10/22/69	2100	7°29' N	145°05' W	-	-	1614	28.8	33.99	-	-	2	-	-	2	3.3, 3.8
Do.	do.	0	C-46-27-2	10/22/69	2300	7°29' N	145°05' W	-	-	1837	28.8	33.99	-	-	1	-	-	1	3.5
Do.	do.	0	C-46-29-2	10/23/69	2300	7°28' N	145°14' W	-	-	1535	28.9	33.85	-	-	1	-	-	1	ca. 2.8
Do.	do.	0	C-46-29-3	10/24/69	0100	7°28' N	145°14' W	-	-	1592	28.8	33.84	-	-	1	-	-	1	3.8
Do.	do.	0	C-46-31-1	10/24/69	2100	7°31' N	145°02' W	-	-	1734	28.9	33.84	-	-	1	-	-	1	3.8
Do.	do.	0	C-46-31-2	10/24/69	2300	7°31' N	145°02' W	-	-	1516	28.8	33.84	-	-	1	-	-	1	3.9
Do.	do.	0	C-46-31-3	10/25/69	0100	7°31' N	145°02' W	-	-	1536	28.8	33.91	-	2	1	-	-	3	4.3-4.5
Do.	do.	0	C-48-46-1	4/15/70	2300	3°22' N	144°56' W	-	-	1744	28.5	34.81	-	-	-	1	-	1	ca. 5.8
Do.	do.	0	C-48-79-1	4/23/70	2100	3°32' S	144°56' W	-	-	1268	28.8	34.92	-	-	-	1	-	1	6.6
Do.	oblique	0-40	S-21-30-1	8/14/53	0240	21°03' N	157°31' W	-	-	1954	26.1	35.16	-	1	-	-	-	1	4.5
Do.	do.	0-60	S-35-8-1	8/2/56	1455	21°12' N	158°22' W	-	-	1641	26.2	-	-	-	1	-	-	1	4.8
Do.	do.	0-60	S-38-64-2	3/5/57	2030	17°56' S	140°28' W	-	-	533	-	-	-	1	-	-	-	1	3.0
Do.	do.	0-60	S-47-14-1	10/19/58	0502	17°40' N	154°34' W	-	-	1253	26.3	34.72	-	1	-	-	-	1	5.5
Do.	do.	0-60	S-50-2	1/11/59	2008	14°42' N	152°21' W	-	-	1154	24.8	34.74	-	-	1	-	-	1	7.2
Do.	do.	0-60	S-50-33	2/3/59	2004	15°52' N	169°54' W	-	-	1394	24.8	34.83	-	-	2	-	-	2	5.9, 6.3
Do.	do.	0-60	G-41-169-1	8/19/58	2331	21°10' N	158°19' W	-	-	1749	26.7	34.91	-	-	1	-	-	1	5.2
Do.	do.	0-60	G-44-24-1	5/21/59	2003	18°03' N	161°03' W	-	-	1458	26.1	34.34	-	-	1	-	-	1	ca. 4.0
Do.	do.	0-60	G-44-32-1	5/30/59	2004	18°03' N	155°14' W	-	-	-	-	-	-	-	2	-	-	2	4.5, 5.1
Do.	do.	0-60	G-45-14-1	7/19/59	2032	20°40' N	163°42' W	-	-	1034	26.7	34.26	-	1	-	-	-	1	5.9
Do.	do.	0-60	G-45-15-1	7/20/59	2030	23°20' N	166°10' W	-	-	1055	26.4	34.70	-	1	-	-	-	1	9.4
Do.	do.	0-60	G-45-22-1	7/24/59	2024	23°07' N	159°00' W	-	-	811	26.7	34.37	-	1	-	1	1	3	Bl 4.0, UN 4.2, BB7.5
Do.	do.	0-60	G-45-29-1	7/29/59	1958	16°48' N	154°38' W	-	-	1284	25.9	-	-	-	-	1	-	1	?
Do.	do.	0-60	G-46-16-B	10/4/59	2034	22°48' N	153°42' W	-	-	1466	-	-	-	-	-	-	1	1	ca. 3.5
Do.	do.	0-60	G-46-21-A	10/10/59	2002	15°33' N	160°15' W	-	-	1421	26.9	34.53	-	-	-	-	1	1	ca. 5.0
Do.	do.	0-60	G-46-23-A	10/12/59	2004	18°08' N	164°57' W	-	-	1397	27.4	34.31	-	1	-	-	-	1	6.8
Do.	do.	0-60	G-52-79-1	4/20/61	0214	18°21' N	168°53' W	-	-	1498	25.4	34.72	-	1	-	-	-	1	4.3
Do.	do.	0-60	G-53-3-1	6/24/61	1130	19°04' N	155°59' W	-	-	1947	26.4	34.51	-	1	1	-	1	3	BL 4.8, SB 3.9, UN 4.3
Do.	do.	0-60	M-35-27-1	5/13/57	1716	22°20' N	157°46' W	-	-	1677	23.4	35.08	-	-	-	1	-	1	ca. 9.8
Do.	do.	0-140	S-43-88-1	2/20/58	2010	7°49' N	148°37' W	-	-	1506	27.8	-	-	1	-	-	-	1	3.9
Do.	do.	0-140	S-45-98-1	5/24/58	0314	6°34' S	139°41' W	-	-	1426	27.9	35.02	-	1	-	-	-	1	4.0
Do.	do.	0-140	S-45-158-1	6/21/58	2010	17°14' N	153°40' W	-	-	1951	25.1	-	-	-	-	1	-	1	6.9
Do.	do.	0-140	S-46- 1	7/22/58	2127	23°56' N	158°28' W	-	-	1623	25.4	-	-	2	-	-	1	3	4.4-6.9
Do.	do.	0-140	G-48-18	6/30/60	0600	17°06' N	173°51' W	-	-	-	27.2	-	-	2	-		-	2	6.0, 6.1

Appendix Table 1.--Record of catches of istiophorid larvae and juveniles by the Southwest Fisheries Center, Honolulu Laboratory from 1950 to 1971.--Continued.

Gear	Type of tow	Depth of tow	Vessel[1]/ cruise/ station sample	Date	Time	Position		Duration of tow		Volume of water strained	Surface temperature	Surface salinity	Larval and juvenile catches[2]						Size range
						Latitude	Longitude						SF	BL	SB	BB	UN	Total	
								Hr.	Min.	m³	° C	°/₀₀							mm
1-m plankton net	oblique	0-140	G-48-35	7/7/60	1801	12°53' N	174°28' E	-	-	-	27.8	-	-	1	-	-	-	1	4.6
Do.	do.	0-140	G-48-54	7/22/60	0600	11°34' N	159°54' E	-	-	-	28.7	-	-	-	-	-	1	1	4.9
Do.	do.	0-140	G-48-104	8/16/60	1800	24°15' N	178°54' E	-	-	-	29.0	-	-	1	-	-	-	1	4.5
Do.	do.	0-140	G-55-26-1	1/29/62	1358	9°40' S	171°38' E	-	-	-	29.2	-	-	1	-	-	-	1	4.9
Do.	do.	0-140	G-55-39-1	2/10/62	0808	23°29' S	168°04' E	-	-	-	25.8	-	-	1	1	-	-	2	BL 8.6, SB 12.8
Do.	do.	0-140	G-55-97-2	3/12/62	0804	18°14' S	172°07' W	-	-	-	27.8	-	-	1	-	-	-	1	5.1
Do.	do.	0-140	G-69-11-2	10/13/63	0759	9°11' N	171°48' W	-	-	-	-	-	-	1	-	-	-	1	3.4
Do.	do.	0-140	G-69-26-2	10/21/63	2002	0°02' S	172°31' E	-	-	-	-	-	-	1	-	-	-	1	4.3
Do.	do.	0-150	S-6-19-3	8/20/50	2311	19°31' N	157°10' W	-	-	4782	26.0	-	-	1	-	-	-	1	21.2
Do.	do.	0-200	S-5-7	7/4/50	1649	15°00' N	171°54' W	-	-	888	26.7	34.56	-	1	-	-	-	1	4.3
Do.	do.	0-200	S-17-21	9/11/52	1930	20°28' N	155°37' W	-	-	1679	25.5	35.05	-	-	1	-	-	1	6.4
Do.	do.	0-200	S-34-7	4/30/56	1540	16°31' N	153°58' W	-	-	2286	24.8	34.42	-	-	1	-	-	1	6.7
Do.	do.	0-200	S-34-136	6/28/56	1402	21°02' N	160°26' W	-	-	1927	25.2	34.92	-	1	-	-	-	1	6.3
Do.	do.	0-200	S-35-101	8/30/56	0803	10°47' S	143°01' W	-	-	1576	26.1	-	-	-	1	-	-	1	7.1
Do.	do.	0-200	S-35-137	9/11/56	0807	16°45' S	149°52' W	-	-	1537	25.9	-	-	-	-	1	1	2	?
Do.	do.	0-200	S-35-158	9/24/56	2110	5°52' S	160°03' W	-	-	1876	26.7	-	-	-	1	-	-	1	4.5
Do.	do.	0-200	S-35-168	9/29/56	2117	4°24' N	160°08' W	-	-	1687	26.9	34.81	-	-	-	1	-	1	?
Cobb trawl	horizontal	15-20	C-32-19	7/20/67	1944	20°59' N	158°30' W	6	0	-	28.0	-	-	1	-	-	-	1	9.2
Do.	do.	8-60	C-32-29	7/26/67	0343	21°00' N	158°32' W	4	12	-	26.0	-	-	2	-	-	-	2	16.6, 18.5
Do.	do.	14-20	C-32-66	9/15/67	0345	19°45' N	156°06' W	6	0	-	28.0	-	-	3	-	-	-	3	13.0-19.5
Do.	do.	87-119	C-32-67	9/15/67	1152	19°53' N	156°05' W	6	0	-	28.3	-	-	1	-	-	-	1	18.9
Do.	do.	13-18	C-32-70	9/16/67	1946	19°24' N	156°00' W	6	0	-	28.3	-	-	2	-	-	-	2	8.6, 10.6
Do.	do.	9-18	C-32-81	9/23/67	1941	21°22' N	158°14' W	6	0		27.5	-	-	1	-	-	-	1	9.8
Do.	do.	20	C-46-25	10/21/69	1948	7°26' N	144°42' W	-	-	-	28.6	-	-	2	-	-	-	2	ca. 12.0, 16.3
Do.	do.	50	C-53-54	4/24/71	1832	19°11' N	147°27' E	2	0	-	28.6	-	-	2	-	-	-	2	22.0, 24.1
Do.	do.	100	C-55-53	11/7/71	0030	21°03' N	147°54' E	2	55	-	28.7	-	-	4	-	-	-	4	20.0-55.0
Neuston net	do.	0	C-55-5	10/24/71	1229	21°52' N	173°05' W	-	30	-	27.8	-	-	-	1	-	-	1	9.2
Do.	do.	0	C-55-13	10/29/71	1230	22°30' N	168°22' E	-	30	-	-	-	-	3	-	-	-	3	5.5-6.1
Do.	do.	0	C-55-21	11/2/71	1230	22°52' N	149°06' E	-	30	-	-	-	-	1	-	-	-	1	10.0
Do.	do.	0	C-55-92	11/12/71	1230	16°17' N	149°16' E	-	30	-	-	-	-	1	-	-	-	1	4.5
Do.	do.	0	C-55-106	11/23/71	1230	6°50' N	163°36' E	-	30	-	-	-	-	2	-	-	-	2	6.7, 9.2
Do.	do.	0	C-55-132	12/1/71	1230	8°07' N	171°14' E	-	30	-	28.7	-	-	17	-	-	-	17	6.6-20.0

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[1] S = Hugh M. Smith, G = Charles H. Gilbert, E = U.S.S. Energy, C = Townsend Cromwell, M = John R. Manning.

Appendix Table 2.--Record of catches of swordfish larvae and juveniles by Southwest Fisheries Center, Honolulu Laboratory from 1950 to 1971.

Gear	Type of tow	Depth of tow	Vessel cruise no.[1]	Station/ no. of samples	Date	Time (local)	Position		Volume of meter	Surface temperature	Surface salinity	Size range (SL)
							Latitude	Longitude				
									m^3	°C	‰	mm
1-m plankton net	Horizontal	0	S-4	15-1	5/21/50	1610	20°13' N	158°30' W	2950	24.5	--	10.5; 19.3
Do.	do.	0	S-4	20-1	5/23/50	0911	20°14' N	157°04' W	3346	23.6	--	6.6
Do.	do.	0	S-4	23-1	5/14/50	1852	22°40' N	157°10' W	2192	23.3	--	9.6
Do.	do.	0	S-39	21-1	5/9/57	2010	23°03' N	165°23' W	--	25.1	35.21	7.3; 8.8; 11.6; 13.4; 15.8
Do.	do.	0	S-39	28-1	5/15/57	2010	20°03' N	162°04' W	--	25.1	34.96	6.5; ca. 7.0; 19.6
Do.	do.	0	E-5	59-1	5/14/64	1815	16°52' N	171°19' W	1785	--	--	8.3
Do.	do.	0	E-6	80-1	6/14/64	1954	15°53' N	173°27' W	1455	--	--	23.0
Do.	do.	0	C-48	46-1	4/15/70	2300	3°22' N	144°56' W	1744	28.5	34.81	5.8
Do.	do.	0	C-48	79-1	4/23/70	2100	3°32' S	144°56' W	1268	28.8	--	6.6
Do.	Oblique	60	M-35	27-1	5/13/57	1716	22°20' N	157°46' W	1677	23.4	35.08	9.8
Do.	do.	60	G-45	22-1	7/24/59	2024	23°07' N	159°00' W	811	26.7	34.37	7.5
Do.	do.	140	S-45	158-1	6/21/58	2010	17°14' W	153°40' W	1951	25.1	--	6.9
Do.	do.	200	S-35	137-1	9/11/56	0807	16°45' S	149°52' W	1537	25.9	--	ca. 8.0 (head only)

[1] C = Townsend Cromwell, E = U.S.S. Energy, G = Charles H. Gilbert, M = John R. Manning, S = Hugh M. Smith.

Distribution of Larval Swordfish in the Northwest Atlantic Ocean

GRETCHEN E. MARKLE[1]

ABSTRACT

Surface plankton collections, mostly with neuston nets towed at 4-5 knots, during eight cruises (1965-1972) yielded 119 swordfish larvae 6-110 mm total length. Captures were grouped in discrete geographical areas: Virgin Islands, Guiana current, Northwest Caribbean, Windward Passage, and Florida current. All collections were made in January-April, but comparison with other published data suggests that this may not be the peak spawning period. Descriptions of swordfish larvae are appended.

In 1965, a program was initiated to study the distribution and early life history of large pelagic fishes in the Northwest Atlantic Ocean. Forty-seven swordfish larvae were captured during the first cruise, which covered the Sargasso Sea, the Virgin Islands, and the Gulf Stream off Florida. Since relatively little is known of the growth and behavior of young swordfish, subsequent cruises were designed to carry out a more systematic search for specimens and to study the environmental conditions under which they occur.

The 1965 data have already been reported (Tibbo and Lauzier, 1969). In this report, all of the data are considered.

MATERIALS AND METHODS

Eight cruises were made during the period 1965-1972 (Table 1). Of these, five were to the Caribbean and adjacent seas, and three were to the Gulf Stream north of lat. 25°N. Most of them were carried out during the months of January, February, and March. Two of the Gulf Stream cruises were in April and May. In all, 280 stations were occupied (Fig. 1).

Table 1.—Fisheries Research Board of Canada swordfish cruises, 1965-1972.

Cruises	Dates	Locations	No. of stations	No. of larvae captured
BIO-3	3-24 Feb. 1965	Sargasso Sea, Virgin Islands Gulf Stream	36	47
ATC-11	25 Jan.-11 Feb. 1966	Gulf Stream	31	9
EEP-3	4-18 Apr. 1967	NE of Cape Hatteras	14	2
Hudson-68	24 Mar-2 Apr. 1968	SE of Barbados	11	8
CODC-69-003	1 Jan-5 Feb. 1969	Sargasso Sea, Lesser Antilles	51	10
CODC-69-023	28 Apr.-19 May 1969	N of Bermuda	19	—
CODC-70-004	14 Feb-13 Mar 1970	Caribbean, Gulf Stream system	50	25
CODC-72-004	25 Feb.-23 Mar. 1972	Lesser Antilles Southern Caribbean, Gulf Stream	68	18
		Total	280	119

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[1] Fisheries Research Board of Canada, Biological Station, St. Andrews, New Brunswick, Canada.

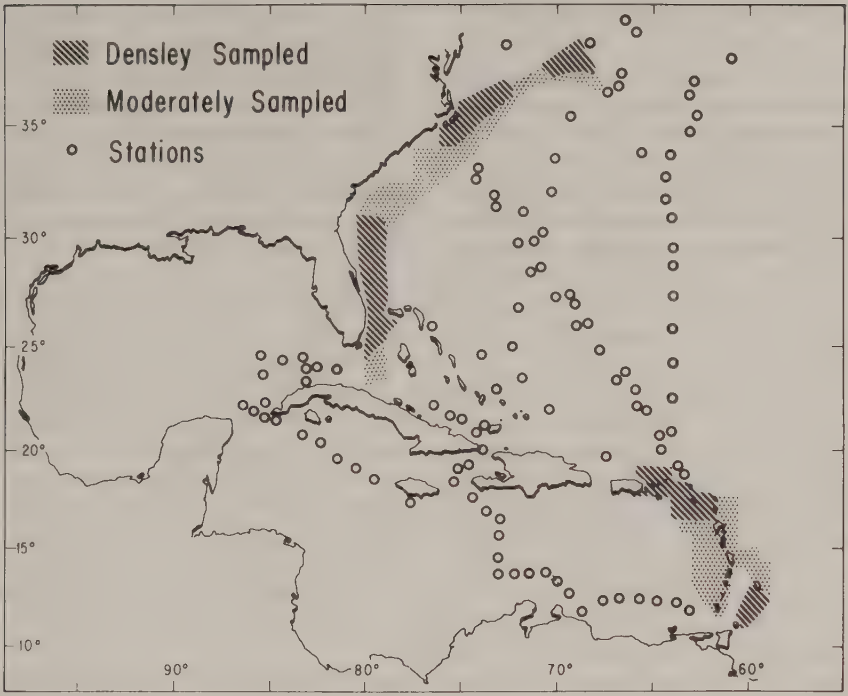

Figure 1.—Sampling areas and stations for Fisheries Research Board of Canada cruises.

At each station, oceanographic data (temperatures, salinities, and oxygen content) were collected, and plankton tows were made. Three types of surface nets (''Lobster,'' ''Neuston,'' and ''Herring'' nets) were used on the 1965 cruise (Tibbo and Lauzier, 1969). On more recent cruises most of the surface sampling was carried out with the ''Neuston'' net, which consists of an oblate meter ring with a 30 × 100 cm opening (Bartlett and Haedrich, 1968). Several deep tows were made with other nets. ''Neuston'' nets were towed at 4-6 knots, while other nets were towed at various speeds from 2 to 5 knots.

RESULTS

During the eight Fisheries Research Board (FRB) cruises a total of 119 swordfish larvae was captured.

These larvae, ranging in size from 6.5 mm to 110.6 mm, were found scattered over a large area (Table 2, Fig. 2), but there was no obvious pattern in size distribution with respect to time or location. Two small larvae were found east of Cape Hatteras in March. Many larvae were caught in the Gulf Stream from the Florida Straits to Cape Hatteras during the months of January through March. Specimens were taken in the northeastern Gulf of Mexico (early March) and south of Cuba (late February). The regions west of the Lesser Antilles and southwest of Barbados were sampled in January and in March, yet larvae were found only in late March. Specimens were obtained in the Virgin Island-Leeward Islands area from January to March.

Sampling in the following areas produced no larvae: Bermuda (January, May); northeast of Cape Hatteras (January, February, April, May); southern Caribbean (late February, early March); southwestern and central Sargasso Sea (January, February).

Although surface temperatures ranged from 6.6°C to 26.9°C, larvae were found only at stations where temperatures were above 22.4°C. Similarly, within a total salinity range of 33.40‰ to 37.88‰ larvae were caught only where the salinity was 35.40‰ or more.

All but three of the larvae were taken in surface tows. The exceptions were caught in oblique tows and hence may have been captured as the net neared the surface (Tibbo and Lauzier, 1969).

DISCUSSIONS AND CONCLUSIONS

Our data alone are insufficient to establish spawning seasons and areas. However, when they are pooled with similar data from other sources (Fig. 3), it can be seen that the greatest densities of swordfish larvae occur in two regions: The Straits of Florida-Cape Hatteras area, and the Virgin Islands-Leeward Islands area. Larvae were also caught in the Gulf Stream northeast of Cape Hatteras (four specimens), in the Gulf of Mexico, northwest Caribbean, southwest of Barbados, west of Lesser Antilles, and in the southern and eastern regions of the Sargasso Sea.

It is believed that some swordfish spawning takes place in the Gulf Stream system from Cuba to Cape Hatteras. Evidence for this is provided by catches of both ripe adults and larvae.

Table 2.—Larval swordfish captures by Fisheries Research Board of Canada.

Location	Date	Temp. (°C)	Swordfish	Total length (mm)
Bermuda	Jan. 1969	≥19.0	—	—
	May 1969	≥20.0	—	—
Northeast of Cape Hatteras	Jan.-Feb. 1966	—	—	—
	Feb. 1970	—	—	—
	Apr. 1967	—	—	—
	Apr.-May 1969	—	—	—
East of Cape Hatteras	Mar. 1967	23.6	2	14.8, 29.5
		23.5	—	—
Gulf Stream, south of Cape Hatteras	Feb. 1965	23.4	24	$\bar{x} = 66.1$
Jacksonville-Savannah area	Jan. 1966	23.7	1	58.3
	Feb. 1965	25.0	1	28.7
Florida coast	Jan. 1966	≥22.4	8	20.8-51.5
	Feb. 1965	25.0	7	18.7-38.9
	Mar. 1970	24.0	1	85.5
	Mar. 1972	≥24.4	5	21.9-110.0
Northeastern Gulf of Mexico	early Mar. 1970	24.4	5	13.0-66.3
Northwestern Caribbean, south of Cuba	late Feb. 1970	≥24.0	12	9.5-41.0
100 miles NE of Jamaica	Feb. 1970	26.6	7	6.0-19.6
Southern Caribbean, west to Jamaica	late Feb.-early Mar. 1972	≥24.0	—	—
Southwest of Barbados	Jan. 1969	≥26.4	—	—
	early Mar. 1972	≥26.0	—	—
	late Mar. 1968	≥26.1	8	$\bar{x} = 28.1$
West of Lesser Antilles	Jan. 1969	≥25.0	—	—
	Mar. 1972	≥25.0	8	$\bar{x} = 37.3$
East of Lesser Antilles	Feb. 1969	≥26.0	—	—
Virgin Islands down to Guadeloupe	Jan.-Feb. 1969	≥25.5	10	33.5-43.9
	Feb. 1965	≥24.6	15	36.5-80.2
	Mar. 1972	≥24.5	5	17.6-60.6
Southwestern and Central Sargasso Sea	Jan. 1969	≥24	—	—
	Feb. 1965	≥24	—	—
	Feb. 1972	≥24	—	—
		Total	119	

Information on the distribution of ripe females is available from both commercial and sportfishing operations. The Georges Bank area has been heavily fished, but there are very few reports of ripe females from this region, although some females bearing maturing eggs have been taken off the New England coast (Fish, 1926; Lee, 1942; Rich, 1947). In contrast, there are numerous accounts of ripe females caught off the northern coast of Cuba (Arata, 1954; Lamonte and Marcy, 1941). According to Lamonte (1944), fishermen and anglers claim that swordfish bearing huge ovaries, with eggs ready to rupture the ovigerous membranes, are frequently found in the Cojimar, Cuba area, often accompanied by another much smaller fish, presumably the male. Such a distribution of ripe adult swordfish suggests that spawning occurs somewhere off the north coast of Cuba, rather than much farther north. The occurrence of small larvae in the Florida Straits of Cape Hatteras region supports this conclusion. However, a single spawning area cannot account for the widespread distribution of larvae.

In the Western Atlantic, it is probable that swordfish spawn in widely scattered areas from which the larvae are further dispersed by currents such as the Gulf Stream. This contrasts with Gorbunova's (1969) conclusion that swordfish spawning in the Pacific is restricted to areas of upwelling, where high productivity provides favorable conditions for both zooplankton and fish feeders such as larval swordfish. Gorbunova (1969) also concluded that young swordfish do not migrate far in the first year and thus are captured quite close to the actual spawning grounds.

In the Western Atlantic, Arata (1954) proposed a large spawning area and an extended spawning period. From larval sizes and the growth rate of 0.6 mm/day suggested by Sanzo (1922), Arata estimated the approximate ages of his specimens, and deduced that peak spawning occurs at approximately the same time in both the Gulf Stream and in the Gulf of Mexico—from May to June in the Gulf Stream and from late April to July in the Gulf of Mexico. Arata (1954) also suggested that larvae may be carried long distances in the Gulf Stream system. Making back calculations based on fish sizes and current speeds, and assuming passive drift

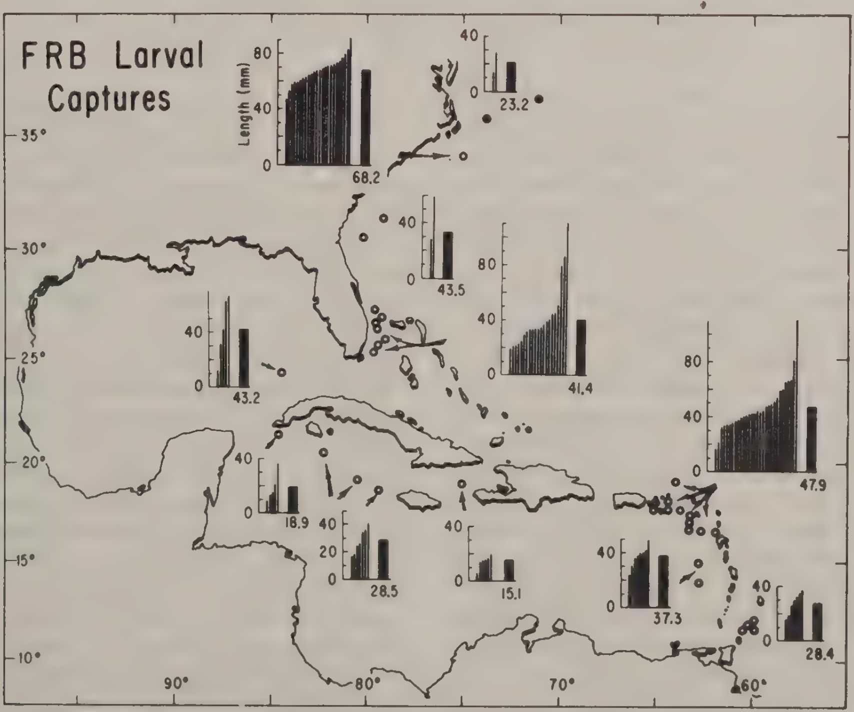

Figure 2.—Numbers, size ranges, and mean lengths of swordfish larvae—Fisheries Research Board of Canada collections.

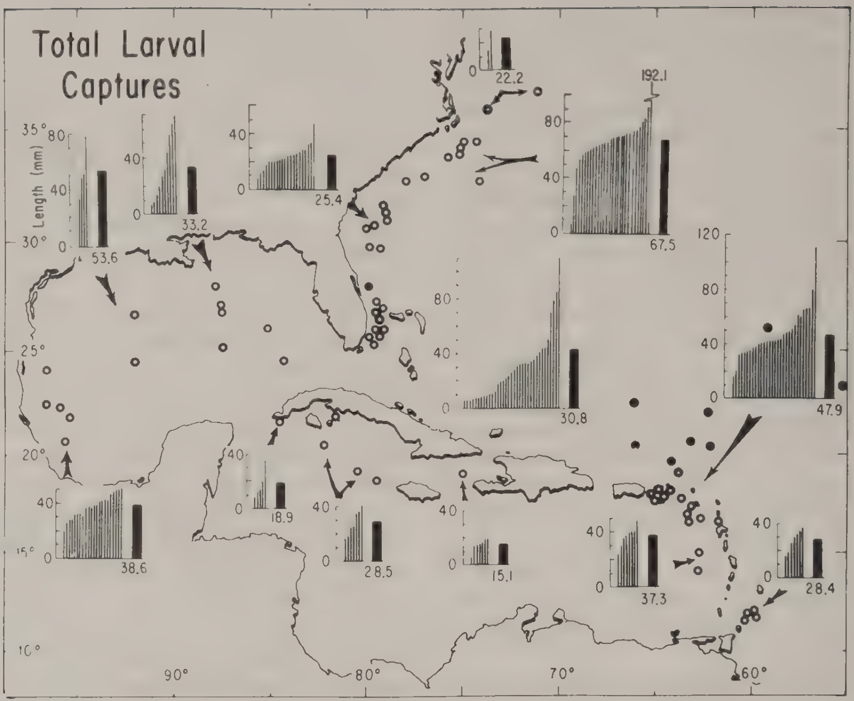

Figure 3.—Numbers, size ranges, and mean lengths of swordfish larvae—collections from various sources including Fisheries Research Board of Canada.

by even the larger (50 mm) larvae, he estimated an overall spawning period from the end of December to the end of September over a large area—from the lower Caribbean through the Yucatan Channel, the Straits of Florida, and the Gulf Stream system northwards to the South Carolina coast, i.e. from about lat. 15°N to about lat. 32°N.

The data presented herein for the most part support Arata's (1954) conclusions, although they cover only the period from January to March. There are, however, a few discrepancies. Arata (1954) suggests that the sizes of his specimens from the northeast ,Gulf of Mexico further substantiate the theory that spawning occurs in the lower Caribbean. For example, he concluded that, considering the current structure, one 55.4 mm specimen in the Gulf of Mexico would most likely have been spawned somewhere south of Jamaica around the first of March. However, sampling in the southern half of the Caribbean from November to April produced no larvae (Ueyanagi et al., 1970).

In his back calculations, Arata (1954) assumed that the major currents moving north from the Caribbean into the Gulf of Mexico do not swing farther west than long. 88°W. Thus, larvae would be carried directly from the Caribbean into the northeastern Gulf. The pilot charts of the North Atlantic and Sverdrup, Johnson, and Fleming (1942) show that, while the major currents do flow directly through the Straits of Florida (Fig. 4), the waters of the Gulf of Mexico form independent eddies. It is these secondary currents which flow into the northeastern Gulf, and which also swing farther west than long. 88°W. The large larvae caught by Arnold (1955) in the southwestern (mean = 38.6 mm) and central (mean = 53.6) areas of the Gulf of Mexico may have been spawned in the southwest part of the Gulf and remained trapped there by the Gulf eddies. On the other hand, the presence of these larvae may indicate that secondary currents are sufficiently strong to transport larvae from the Caribbean into the western reaches of the Gulf. Thus, larvae from the Caribbean could take a longer route to the northeast, initially via the more westerly currents. Back calculations for the large specimens would then place their spawning areas somewhere in the northwest Caribbean where several small larvae have been found.

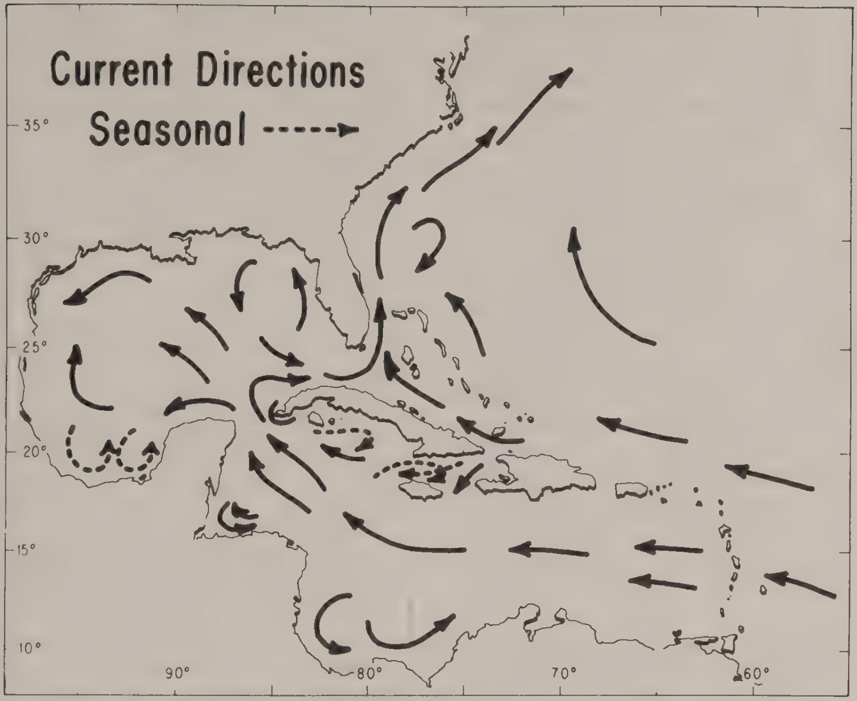

Figure 4.—Surface water circulation in the study area.

From data collected on the 1965 cruise, Tibbo and Lauzier (1969) proposed a spawning ground for Gulf Stream larvae west of the Straits of Florida. They assumed that larvae from both the Florida Straits and Cape Hatteras areas came from the same spawning area. From this, they calculated a growth rate of 2mm/day and, using back calculations similar to Arata's, placed the spawning grounds in the southern Gulf of Mexico, and probably in the Yucatan Channel. However, when other data are considered, it is obvious that this region is not the only spawning ground in the western Caribbean. Similar calculations show that larvae caught off the coast of South Carolina would have hatched just south of the Florida Keys, while the larger larvae could conceivably have come from as far away as the eastern Caribbean.

Such back calculations are only approximations since they assume uniform movement of water masses and passive drift by the larvae. However, even very young swordfish are active swimmers and no allowance can be made in the calculations for any active movement by the larvae.

There are probably two distinct spawning areas farther east, one southeast of Barbados, and the other in the Virgin Islands-Southern Sargasso Sea region.

Spawning probably begins sometime early in the year southeast of Barbados. By March, young larvae would have drifted into the Barbados area, and west of the Lesser Antilles. This would account for the sudden occurrence of 30 mm larvae in late March, despite the absence of larvae in these areas earlier in the year. The patchiness of the distribution west of the Antilles could be due to interference patterns produced by currents flowing between the scattered Windward Islands. Larvae carried by these currents would tend to collect at the "nodes" of the pattern.

Tåning (1955) sampled the Virgin Islands-Sargasso Sea region year round, although his efforts during July to September were minimal. Considering only those months with more than 100 h of fishing, he found that the largest catches were in February, March, and April. Although our cruises accumulated only 70 h total fishing in this area during the months of January, February, and March, larvae were caught in all of these times, with peak catches in February. It is possible that more intensive sampling from July to September would show this time to be equally productive, since Tåning (1955) obtained several larvae during these months despite low fishing effort.

Temperature and Salinity Relationships

On the basis of larval catches, it is believed that swordfish do not spawn in waters less than about 23°C. At one station where swordfish larvae were found, the surface temperature was 22.4°C, but at all other stations it exceeded 23.4°C. Other authors report similar findings (Arata, 1954; Tåning, 1955; Kondritskaya, 1970). Spawning also apparently occurs only within a narrow range of salinities. Arata (1954) found larvae only in areas with salinities of 35.75‰ or more. FRB sampled a wider range of salinities than did Arata, and also found larvae at lower salinities. One station had a salinity of 35.40‰. At all other larval stations, the salinity was 35.46‰ or more.

Thus, while the lower salinity limit remains indefinite, it must be around 35.5‰. No estimate can be made of the upper salinity limit since both the FRB and Arata (1954) investigations found larvae at the highest salinities sampled.

It should be noted that while temperatures and salinities may play an important role in the location of spawning grounds, these cannot be the sole determining factors, since very many stations with "ideal" temperature and salinity conditions produced no larvae.

Vertical Distribution of Larvae and Time of Capture

Swordfish larvae appear to frequent surface waters. All but three of our specimens were caught in surface nets. Arata (1954) reported that 70-m oblique tows at each station captured only one larva. However, when the same equipment was used for one 30-min surface tow, it netted three small specimens. Most other larval captures were made using dipnets (Arata, 1954; Arnold, 1955; Gorbunova, 1969) or a variety of nets towed horizontally at the surface. Tåning (1955) used a 1½ to 2-m ring net towed in the upper 30 m. Rivers (1966) reports 113 larvae caught in a single cruise with a 1-m nekton ring net. Gorbunova (1969) caught most of her specimens using a pleuston net in the upper 30 cm.

Gorbunova (1969) and Parin (1967) consider feeding behavior in explaining the predominances of larvae at the surface. They found that larvae were most abundant in the catches in the morning and evening and postulated that these twilight hours coincide with the periods of most intensive feeding. Presumably, at these hours the swordfish rise into the more productive surface layers to feed. At midday and at night, they disperse away from the surface. In contrast, Arata (1954) obtained his best catches by day (only three specimens were caught at night). Arnold (1955) caught most of his specimens at night though he may have attracted the larvae by nightlighting.

Our data do not suggest such periodicity of occurrence at the surface. Catch rates are similar for both the day (0600-1800) and night (1800-0800) hours. Nor is there any apparent increase in catch rate during the twilight hours.

Not all surface tows take larvae. Tåning (1955) noted that, while larger nets were successful, a ½-m ring net was easily avoided by even small larvae. In general, larvae more than 70-80 mm in length are seldom taken even in large nets towed at high speeds.

SUMMARY

From 1965 to 1972, eight cruises were made to the Caribbean and adjacent seas and to the Gulf Stream. Plankton nets were towed and oceanographic observations were made at 280 stations.

Altogether 119 swordfish larvae from 6.5 to 110.6 mm were found in the following areas: Gulf Stream system from Florida to Cape Hatteras, northeastern Gulf of Mexico, northwestern Caribbean, west of Lesser Antilles, southwest of Barbados, and Virgin Islands.

There appears to be an extensive spawning area in the northwestern Caribbean, Gulf of Mexico, and in the Gulf Stream system north to Cape Hatteras. Two other spawning areas are proposed: one southeast of Barbados, and one in the Southern Sargasso Sea-Virgin Islands area.

Swordfish larvae are seldom found in temperatures below 23.5°C. They were found only in waters with a salinity of 35.4‰ or more.

The larvae were caught almost exclusively in surface nets. Although other authors have suggested daily periodicity in larval abundance at the surface, catch rates for our collections were comparable for all periods of the day.

ACKNOWLEDGMENTS

The author wishes to especially thank the staff of the Pelagic Program at St. Andrews (especially James Beckett) for making the data available and for their assistance in the writing of this paper. I would also like to thank the Royal Ontario Museum and the Canadian Hydrographic Service for the part they played in collecting the data.

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APPENDIX: DESCRIPTIONS OF SWORDFISH *(XIPHIAS GLADIUS)* LARVAE

All specimens were fixed in Formalin,[2] and then stored in alcohol. Hence, the pigment may have faded or become discolored.

6.0 mm— The larva is opaque white with scattered chromatophores on the snout, head, and body. The mandible is longer than the upper jaw. The teeth are beginning to develop. There are 7-8 supraorbital spines, and 5 preopercular spines—3 small ones at right angles to the lateral surface of the preopercule, and 2 long, thin ones at right angles to the preopercular margin. There is evidence of fin rays in the fin folds. The eyeball has a distinct invagination of the lower curvature.

9.5 mm— The body is much more heavily pigmented. The upper jaw has become slightly longer than the mandible. The teeth are better developed. Some spines have become evident on the snout and head and on the body in two longitudinal rows—one dorsolateral and one ventrolateral. The fin rays have begun to develop in the caudal fin. The dorsal and anal fin rays are well developed. The eyeball is still invaginated.

16.5 mm—The dorsal pigment shows some evidence of vertical barring and some pigment is now present on the dorsal and caudal fins. The upper jaw is noticeably longer than the mandible. The teeth are well developed. The spines on the snout, head, and body have become larger and are more numerous. All the fins have well-developed rays. The eyeball is still invaginated.

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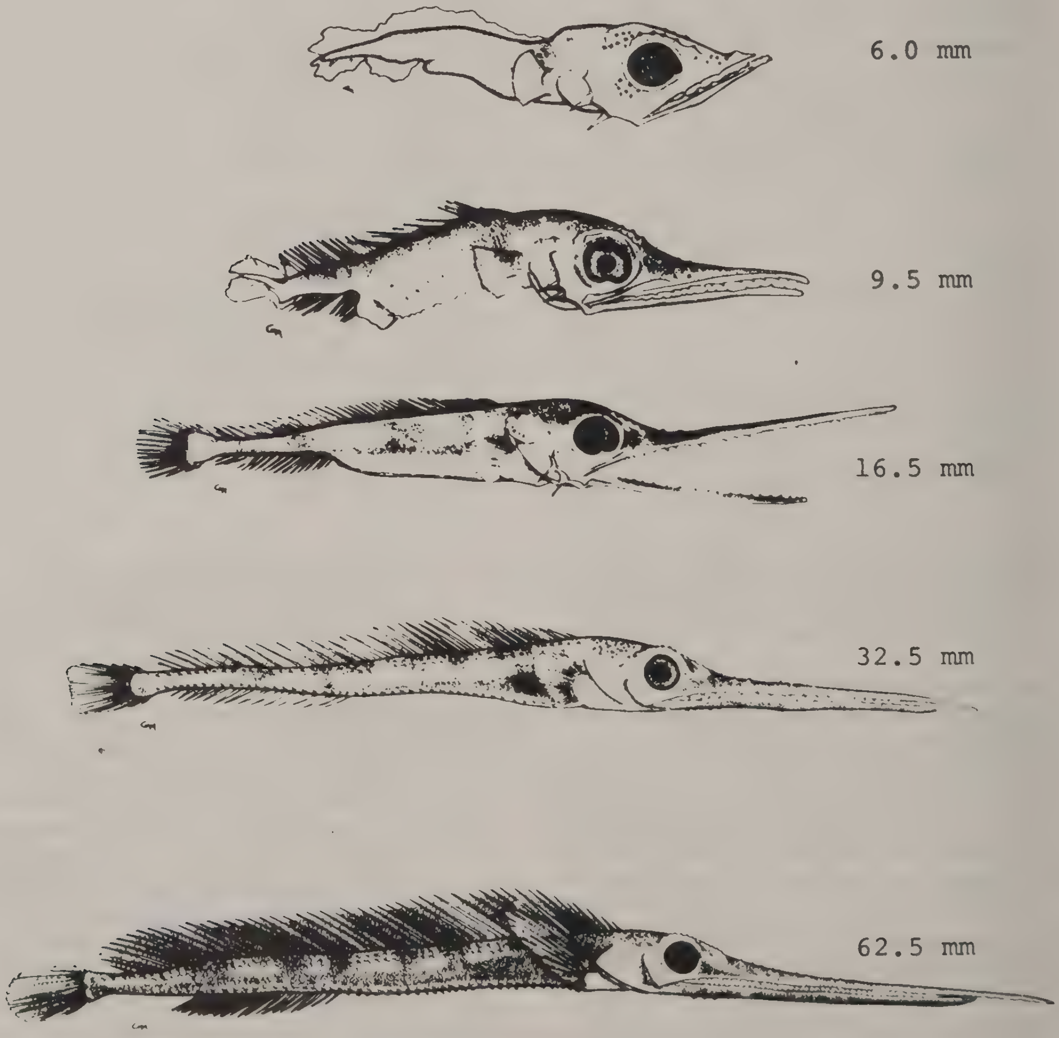
[2] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

32.5 mm—The dorsal barring has become much more pronounced and appears to consist of four or five "double bars". Pigment is much darker in the dorsal and caudal fins and has extended into the anal fin. Spines have developed on the ventral surface of the snout and have become much more pronounced on the body. The two long preopercular spines have become greatly reduced. The eyeball is no longer invaginated.

62.5 mm—The pigment is more definite in both the "double bars" and in all the fins except the pectorals, which still lack pigment. Both jaws, the head, and the body are covered with regular rows of fine spines.



Appendix Figure 1.—Drawings of swordfish larvae of various lengths.

The Distribution of the Larvae of Swordfish, *Xiphias gladius,* in the Indian and Pacific Oceans

YASUO NISHIKAWA and SHOJI UEYANAGI[1]

ABSTRACT

The distribution of larval swordfish, *Xiphias gladius,* was determined on the basis of 325 specimens collected from Japanese research vessels operating in the Indian and Pacific Oceans. These larvae, ranging from 3 to 160 mm in total length, were caught by larva-net tows and by dip netting.

The larvae are distributed over virtually the entire tropical and subtropical areas of the Pacific Ocean except for the eastern Pacific east of long. 100°W. The northernmost occurrence was at lat. 31°N, long. 132°E, near Kyushu in the western Pacific, and the southernmost was at lat. 22°38′S, long. 105°24′W in the eastern Pacific. Data were insufficient to delineate the distribution in the Indian Ocean.

The surface water temperature in the areas of larval swordfish occurrence ranged from 24.1° to 30.7°C.

The distribution of larval swordfish, *Xiphias gladius,* in the Indian and Pacific Oceans was determined on the basis of 325 specimens collected from Japanese research vessels. These larvae were collected largely by larva-net tows and included the 26 specimens previously described by Yabe et al. (1959). The results from this study supplement the findings on larval swordfish occurrence in the Indian and Pacific Oceans by Tåning (1955), Yabe et al. (1959), and Gorbunova (1969). The method of collection was as described by Ueyanagi (1969) and included surface tows as well as simultaneous surface (0-2 m) and subsurface (20-30 m) horizontal larva-net tows.

SIZE OF THE LARVAE

The 318 larvae collected by larva-net tows ranged in total length from 3 to 160 mm. Seven specimens taken by dip netting measured 34-80 mm. The length-frequency distribution of 280 larvae taken by net tows is shown in Figure 1.

A very large proportion of the larvae was centered around the 5 mm length class. The numbers rapidly decreased between 5 and 10 mm, after which they leveled off to about 30 mm. Very few larvae exceeded 50 mm in total length.

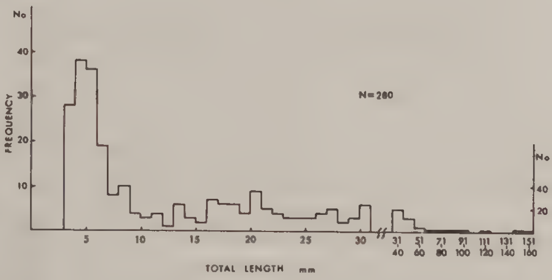


Figure 1.—Length-frequency distribution of swordfish larvae collected by larva-net tows.

VERTICAL DISTRIBUTION

The fact that the larvae of swordfish are distributed largely at the surface is well known (Tåning, 1955; Yabe et al., 1959; Gorbunova, 1969). The vertical distribution was further examined for possible day-night differences (Fig. 2). The catches in surface (0-2 m) and subsurface (20-30 m) tows were compared through relative densities represented by the percentage of occurrence, as follows:

$$\text{Surface} = \frac{\text{Number of surface tows on which larvae were caught} \times 100}{\text{Total number of simultaneous tows on which larvae were caught}}$$

$$\text{Subsurface} = \frac{\text{Number of subsurface tows on which larvae were caught} \times 100}{\text{Total number of simultaneous tows on which larvae were caught}}$$

As seen in Figure 2, the density of larvae was greater at the surface both during the day and night.

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[1] Far Seas Fisheries Research Laboratory, Shimizu, Japan.

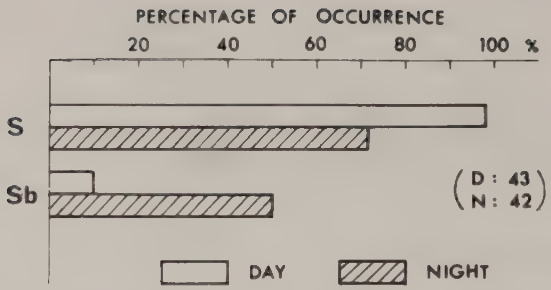

Figure 2.—Vertical distribution of swordfish larvae as seen from catches in surface (S) and subsurface (Sb) larva-net tows. The numbers of day (D) and night (N) stations at which larvae were caught are shown in parentheses.

The difference between the surface and subsurface catches was quite marked during the day but not as much during the night. This difference probably represents diurnal vertical movements among larval swordfish.

GEOGRAPHICAL DISTRIBUTION

The occurrence of larvae was plotted by unit areas of 1° squares (Fig. 3). Also included in the same figure are the areas of relatively high catch rates for adult swordfish. The adult catch rates were based on 1970 data from the Japanese longline fishery, and included unit areas of 5° squares where the annual average catches exceeded 1.0 fish per 1000 hooks fished. (All unit areas where the total fishing effort consisted of less than 20,000 hooks were excluded.)

The distribution of the larvae is seen to be continuous in tropical and subtropical waters extending from the central Indian Ocean clear across to the eastern Pacific Ocean in the vicinity of long. 120°W. The apparent absence of larvae in the South China Sea and in the western Indian Ocean is probably attributable to lack of sufficient sampling effort in those waters since Tåning (1955) and Gorbunova (1969) have shown the presence of larvae in these areas.

The northernmost record of larval occurrence in the western Pacific was at lat. 31°N, long. 132°E, in the vicinity of Kyushu. In the central Pacific it was at lat. 25°N, long. 158°W, just to the north of the Hawaiian Islands, and in the eastern Pacific, at lat. 9°N, long. 120°W. The southernmost occurrence in the southwestern Pacific was at lat. 22°S, long. 170°E, and in the southeastern Pacific at lat. 22°38′S, long. 105°24′W. Although no larvae were caught in waters south of lat. 10°S in the central

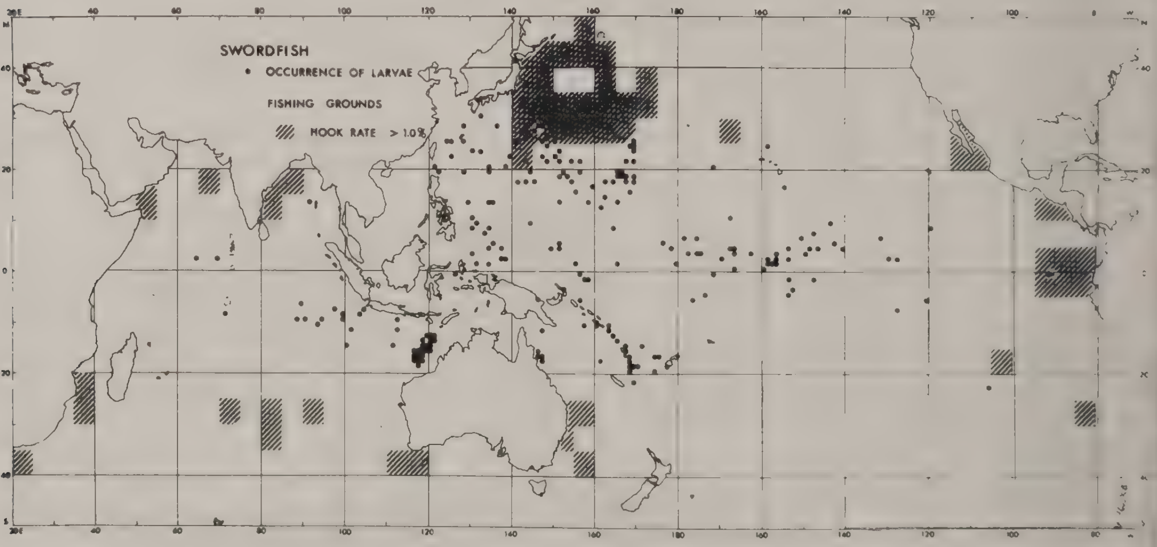

Figure 3.—Distribution of swordfish larvae (dots) and adults (hatched) in the Pacific and Indian Oceans. The adult distribution is represented by areas in which longline catches averaged greater than 1.0 fish per 1000 hooks during 1970, and where fishing effort exceeded 20,000 hooks fished.

South Pacific Ocean (between long. 120°W and 180°), this again may be due to insufficient sampling effort since Gorbunova (1969) showed the presence of larvae in this general area. On the other hand, the absence of larvae along the equator to the east of long. 140°W, and in the waters south of the equator to the east of long. 100°W is probably due to the effect of low temperature waters of the Equatorial Upwelling, Peru Current and the extension of the Peru Current.

It has been shown by Tåning (1955) and Gorbunova (1969) that swordfish larvae occur in waters with surface temperatures higher than 24°C. The present data confirm these reports since larvae have been found in waters with temperatures ranging between 24.1° and 30.7°C.

In order to describe accurately the distribution of larval swordfish in the Pacific Ocean, further information is needed from the central South Pacific and the eastern Pacific areas. It can be generalized, however, that the larvae are distributed very broadly in the north-south direction in the western Pacific and distributed more narrowly in the eastern Pacific. This pattern of distribution appears to be governed by the positions of the 24°C surface isotherm.

As already mentioned, the absence of larvae from the western Indian Ocean was very probably due to insufficient sampling effort, since Gorbunova (1969) showed larvae occurring in waters east of Madagascar Island. In the Indian Ocean, also, it seems that the southern limit of distribution, at least, is determined by the location of the 24°C surface isotherm.

SPAWNING OF SWORDFISH

To derive some information on the spawning of swordfish, the size composition of larvae collected from the western Pacific in waters between lat. 20°N and 20°S was plotted (Fig. 4). This large area was grouped on the assumption that 24°C is the lower temperature limit for swordfish spawning, and since water temperature remains higher than 24°C throughout the year in this area.

Newly hatched larvae, under 10 mm, were taken during all quarters of the year, indicating that spawning is taking place throughout the year in tropical and subtropical waters, at least in the western Pacific. If it is true that 24°C is the limiting temperature, then it also follows that if there is any spawning in higher latitudes, it would be highly seasonal and limited to periods when temperatures are above 24°C.

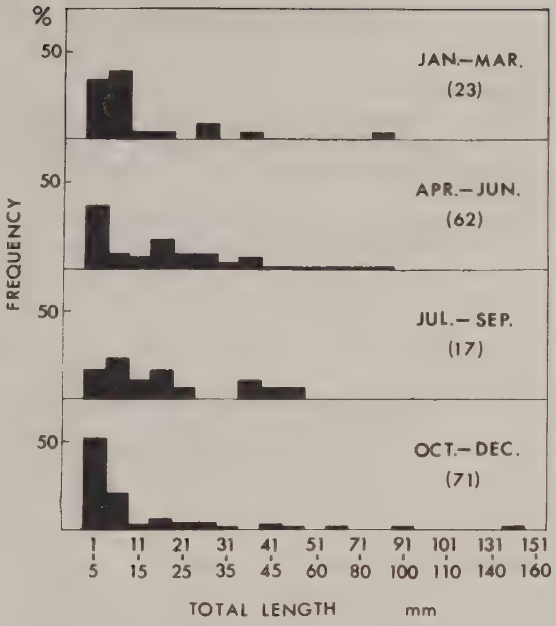

Figure 4.—Length-frequency distribution of larval swordfish, by quarters, taken in tropical and subtropical western Pacific Ocean between lat. 20°N and 20°S. (The number of larvae sampled in each quarter is shown in parentheses.)

The areas of relatively high density of adult swordfish are separate and appear to surround the areas of larval distribution (Fig. 3). They are generally located in the high-latitude, low-temperature areas. In the Pacific, these areas can be roughly divided into the northwestern Pacific, eastern Pacific, and the southwestern Pacific. Whether fish of different subpopulations occur in these areas is not now clear. Perhaps a more detailed study of the temporal and areal distribution of larvae will contribute toward the understanding of the population structure of the swordfish.

ACKNOWLEDGMENT

We especially wish to thank Tamio Otsu of the National Marine Fisheries Service, Honolulu, who read the manuscript and helped us with the English translation. We also wish to thank Kazuko Daito who prepared the illustrations.

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Notes on the Tracking of the Pacific Blue Marlin, *Makaira nigricans*

HEENY S. H. YUEN, ANDREW E. DIZON, and JAMES H. UCHIYAMA[1]

ABSTRACT

In July of 1971 and 1972 five Pacific blue marlin, *Makaira nigricans*, were tagged with temperature sensing, ultrasonic transmitters off the west coast of Hawaii. These were tracked for durations up to 22½ h. The paths of three showed movement in a northerly direction. The other two showed no movement. Average swimming speed ranged from 2.2 km/h to 3.4 km/h for the three fish tracked. Swimming depths differed considerably among the three.

The Pacific blue marlin, *Makaira nigricans*, found off the Kona coast on the west side of the island of Hawaii has attracted sport fishermen from all over the world. Veteran anglers of that area usually fish where the bottom slopes steeply from 200 to 2,000 m; but movement patterns of this prized fish, if patterns do indeed exist, are unknown.

The Honolulu Laboratory of the National Marine Fisheries Service initiated a project in 1971 to study the movements of the blue marlin using a fish tag that transmitted ultrasonic pulses. The research ship, *Charles H. Gilbert*, tracked one blue marlin during 13-16 July 1971, and four during 24-29 July 1972. Fish were tracked for periods ranging from 1 to 22½ h. Path, depth, and speed of swimming are reported.

MATERIALS AND METHODS

Transmitter and Receiving Equipment

The basic unit of the system is the ultrasonic tag. The tag, cylindrical with faired ends, measures 16.5 cm long and 1.8 cm in diameter (Fig. 1a). It produces a 50 kHz carrier signal with a pulse rate that is a function of the surrounding water temperature. Estimation of depth of fish is then possible. The tags have a temperature range of 7°-27°C, an active life of 10 days, and a reception range of about 1.2 km with the equipment aboard *Charles H. Gilbert*.

The tags are attached to the fish with a leader of fine monel wire rope (0.7 mm diameter). The 25-cm leader is embedded at one end of the tag and crimped to an anchor plate of curved, stainless steel (Fig. lb). The plate is 7.4 by 1.8 cm with a sharpened end. A specially tooled rod at the end of 2½ m pole (Fig. 1c) is used to force the anchor plate into the back of the marlin. The drag of the tag and the curvature of the plate move the plate into position under the skin. The toughness of the skin holds the plate in place.

Ultrasonic signals are received via a hydrophone (Honeywell, model HX-74C[2]) mounted in a well in the hull of *Charles H. Gilbert* and a low-frequency receiver (Lawson) mounted on the bridge. Pulse frequency is determined by visually displaying output signals on a storage oscilloscope (Tektronix, model 564). Sensitivity of the hydrophone to 50 kHz transmission is minus 70 db volt/microbar. The cone-shaped beam of the hydrophone has a width of 25° at the minus 3 db level. The hydrophone can be rotated horizontally 125° on both sides of the bow and vertically 90° by electric scan motors controlled by the tracker on the bridge.

Capture and Tagging of Blue Marlin

Bart Miller and his sport fishing boat, *Christel*, (Kona, Hawaii) were engaged to catch and tag marlins. Fish were caught by trolling. As soon as a marlin struck, the line was pulled in by hand to bring

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[1] NOAA, National Marine Fisheries Service, Southwest Fisheries Center, Honolulu Laboratory, Honolulu, HI 96812.

[2] Reference to trade names in this publication does not imply endorsement of commercial products by the National Marine Fisheries Service.

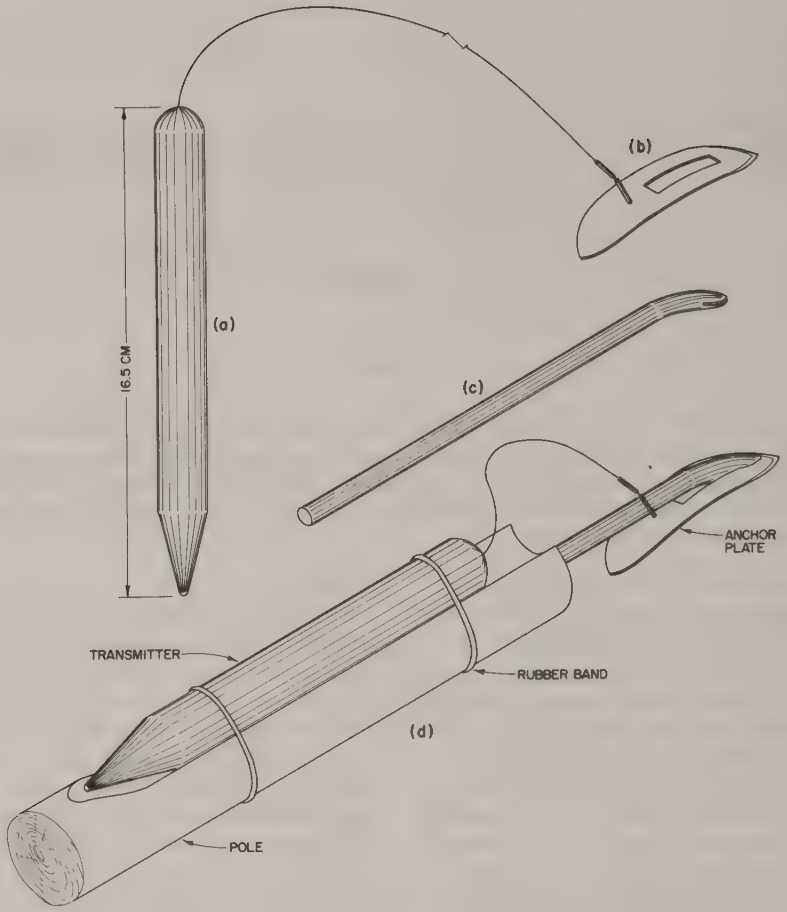


Figure 1.—Ultrasonic transmitter and tagging apparatus. **a.** Temperature sensing transmitter. **b.** Anchor plate. **c.** Rod for applying anchor plate. **d.** All items assembled.

the fish alongside as quickly as possible. When the fish was alongside the boat, its condition was checked and its size was estimated. If the fish appeared to be in good condition, the tag was inserted and the fishing line was cut to release the fish.

Many of the people of the sportfishing community took an active interest in the tracking project. As a result several fishermen offered to donate their marlins. Upon receiving radio communication that a fisherman was willing to donate a hooked marlin, *Christel* transferred the tag, harpoon, and sometimes a crew member. Tagging operations on the other boats were similar to those aboard *Christel*.

Tracking Procedures

During the catching and tagging operation *Charles H. Gilbert* was positioned 200-300 m away from th fishing boat. Upon release of the fish, the followin data were recorded at 5-min intervals: time, ship heading, relative bearing of the hydrophone, ti angle of the hydrophone, and pulse rate of the tag Ship's position was determined and recorded half-hour intervals. Because of poor signal-to-nois ratios, it was not always possible to measure th pulse rate. Because of a malfunction in the tilt ang indicator during the 1972 operations, the observ was sure of the tilt angle only when the hydropho was at 0° or 90°.

The ship was guided to maintain a distance approximately 800 m from the estimated position the tagged marlin. Actual distance between ship a fish continually varied from about 400 to 1,200 m f the following reasons: (1) the minimum forwa speed of the ship was 4 knots; (2) the ship was not permitted to go astern because the cavitation bubbles from the propeller would completely block the tag signals; (3) the distance between tag and ship could only be estimated from the strength of the signals from the tag.

A bathythermograph cast was made every 4 h to obtain temperature-depth profiles. These profiles and the temperature-dependent pulse rates of the tags enabled estimation of swimming depth of the marlin.

RESULTS

Five blue marlin were tagged and tracked, one on 14-15 July 1971 and four between 25 and 28 July 1972. Dates, size of fish, duration of tracking and remarks on each fish are listed in Table 1.

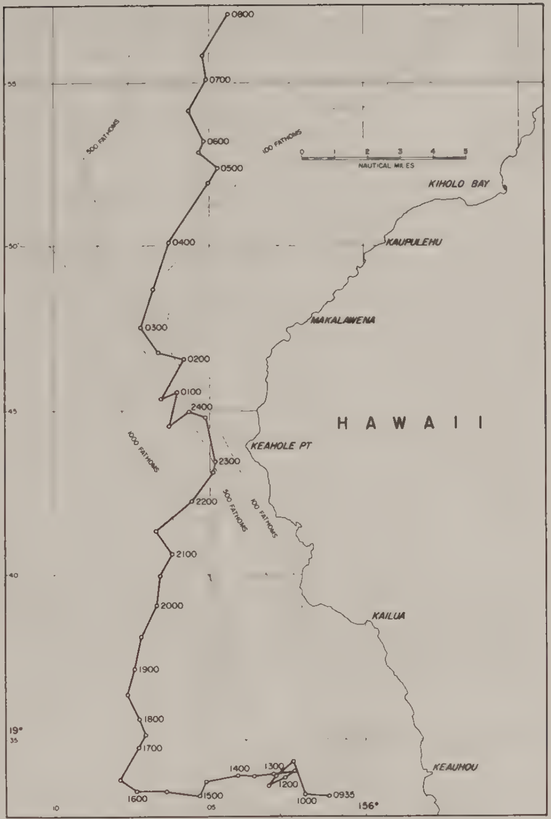
The first tagged marlin was tracked for 22 h 25 min before an equipment breakdown forced a stop. The second fish was in doubtful condition when released. It was difficult to track and contact with it was lost after an hour. The third marlin was tracked for 5 h 22 min before it was lost because of a tactical error. Marlin #4 was abandoned after 7 h because it remained stationary on the bottom soon after it was tagged. After 2 h of swimming the fifth marlin also went to the bottom.

Path

The paths of the marlin tracked are shown in Figures 2 and 3. The path of the last marlin is, of course, of questionable value as the fish lived only 2 h after being tagged. A feature that stands out is that all three marlin moved in a northerly direction. North of Keahole Point there is only one instance where the

Table 1.—Data on blue marlin tagged.

Marlin No.	Estimated weight	Date tagged	Duration tracked	Remarks
	kg (lb)		*h*	
1	270 (600)	7/14/71	22½	Lost—equipment failure.
2	225 (500)	7/25/72	1	Lost—no movement.
3	135 (300)	7/25/72	5½	Lost—tactical error.
4	160 (350)	7/27/72	7½	Abandoned—no movement.
5	70 (150)	7/28/72	8	Abandoned—no movement after 2 h.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0935
500 FATHOMS
100 FATHOMS
1000 FATHOMS
500 FATHOMS
100 FATHOMS
0 1 2 3 4 5
NAUTICAL MILES
KIHOLO BAY
KAUPULEHU
MAKALAWENA
H A W A I I
KEAHOLE PT
KAILUA
KEAUHOU
55
50'
45
40
19° 35
10
05
156°

Figure 2.—Path of blue marlin tracked in 1971. Numbers along track denote hour of day.

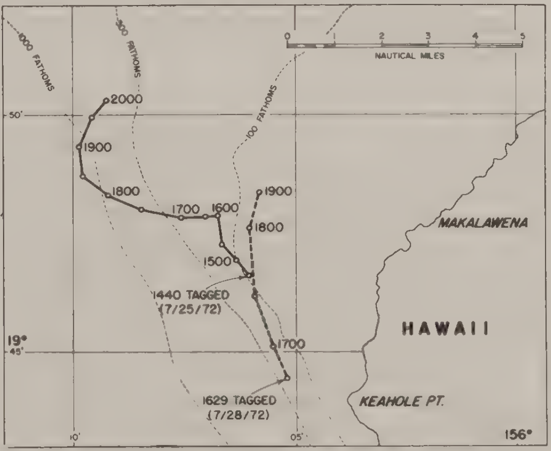
1000 FATHOMS
500 FATHOMS
100 FATHOMS
0 1 2 3 4 5
NAUTICAL MILES
2000
1900
1800
1700
1600
1500
1440 TAGGED (7/25/72)
1900
1800
1700
1629 TAGGED (7/28/72)
MAKALAWENA
HAWAII
KEAHOLE PT.
50'
19° 45'
10'
05'
156°

Figure 3.—Path of two blue marlin tracked in 1972. Numbers along track denote hour of day.

marlin ventured beyond a bottom depth of 2,000 m (Fig. 3). This marlin appeared to be returning to shallower water when contact with it was lost.

Swimming Depths

The choices of swimming depths were quite different among the three marlin tracked. The largest marlin (#1), estimated at 270 kg (600 lb), spent half of the time within 10 m of the surface, a sixth of the time between 10 and 30 m, and the remaining third of the time deeper than 30 m. The maximum swimming depth, which was 80 m, was reached only on one occasion. The next largest marlin tracked (about 135 kg or 300 lb) remained at depths between 115 and 185 m throughout the 5½ h that it was tracked. The last and smallest blue marlin tracked (about 70 kg or 150 lb) remained in a depth zone of 60-85 m before it went to the bottom after 2 h.

The vertical movements of the largest marlin did not show any pattern that could be related to time of day. The other marlin were not tracked long enough to determine if any pattern existed.

Swimming Speeds

Swimming speeds of the three marlin were calculated based on the distance traveled every half hour. Results are in Table 2. The average swimming speed of the last marlin is high compared with the others especially in terms of body lengths per second. Marlin #1 and #3 had an average swimming speed of 0.23 body length/sec. Marlin #5, in contrast, averaged 0.45 body length/sec. The higher speed of the last marlin may be a reflection of the distress of a dying marlin.

The maximum for the largest (#1) and the smallest fish (#5) were 0.62 and 0.68 body length/sec compared with 0.32 body length/sec for marlin #3. The two larger marlin (#1 and #3) both had minimum speeds of 0.09 body length/sec while the minimum speed of the smallest was 0.19 body length/sec.

DISCUSSION

A counterclockwise eddy west of the northern half of the island of Hawaii persists there most of the time (R. A. Barkley, pers. comm.). The area of our marlin tracking coincides with that part of the eddy which flows northward. The fact that all three marlin tracked exhibited a northerly movement suggests the possibility that the blue marlin orients or drifts with currents.

One of the problems in tracking marlin is getting one that will survive the trauma of being caught. Of the five marlin tagged two died and one probably died. Three others were caught and not tagged because of their poor condition. To enhance the probabilities of success in marlin tracking, consideration should be given to ways of attaching the tag without catching the fish.

ACKNOWLEDGMENT

We wish to acknowledge the generosity and cooperation of anglers Alex Smith and Darrell Turne and skipper Monty Brown and Wes Vannatta fo donating their catch for tagging. Special thanks go t Bart Miller and his mate, Murray Mathews, of th boat *Christel* for their enthusiasm and patience. W also wish to thank Jack Benson and the students o his Marine Technology training course of Leewar Community College.

Table 2.—Swimming speeds of blue marlin.

Marlin No.	Minimum km/h	Minimum knots	Minimum body-length/sec	Maximum km/h	Maximum knots	Maximum body-length/sec	Average km/h	Average knots	Average body-length/sec
1	1.1	0.6	0.09	8.2	4.4	0.62	3.0	1.6	0.23
3	0.9	0.5	0.09	3.1	1.7	0.32	2.2	1.2	0.23
5	1.5	0.8	0.19	5.4	2.9	0.68	3.4	1.9	0.45

An Analysis of the Sportfishery For Billfishes in the Northeastern Gulf of Mexico During 1971

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and
LUIS R. RIVAS[2]

ABSTRACT

Data were obtained on the sportfishery for billfishes off South Pass, Louisiana, and off northwest Florida in 1971. These data included: dates and times of raises, hookups, and catches by species; locations of raises; areas fished; baits used; water color; surface conditions; boat characteristics. A total of 99 blue marlin *(Makaira nigricans)*, 284 white marlin *(Tetrapturus albidus)*, and 318 sailfish *(Istiophorus platypterus)* was caught and recorded during 11,107 hours of fishing in the northeastern Gulf of Mexico. White marlin was most abundant in July and August, while sailfish was most abundant in the latter half of September off northwest Florida. Similar periods of abundance for these two species were not evident off South Pass. Blue marlin did not have an especially abundant period in either area. White marlin and sailfish were more abundant off northwest Florida than off South Pass, whereas the reverse was true for blue marlin. The hours of greatest relative abundance for all species of billfishes combined were between 1000 and 1200 and again between 1300 and 1500 off South Pass. A similar pattern was found off northwest Florida (1000-1100 and 1400-1500). Results indicated that the bluer the water, the greater the relative abundance of each of the three species. Off South Pass more billfishes were raised along lines and rips than in any other surface condition, whereas off northwest Florida, more billfishes were raised in open water than in any other surface condition. Moon phase appeared not to have any significant effect on billfishing. Neither did the length of the fishing boats. However, of the boats in the 40 to 49 ft length category, those with twin screws raised more billfishes than those with single screw. Off northwest Florida, blue marlin preferred mullet *(Mugil cephalus)* over ballyhoo *(Hemiramphus* sp.) and bonito *(Euthynnus alleteratus)* strip as bait; white marlin showed no preference; while sailfish preferred bonito strip. Off South Pass, data on bait preference were insufficient to allow conclusions.

The sportfishery for billfishes in the northeastern Gulf of Mexico began in the mid-1950's. Although sailfish *(Istiophorus platypterus)* were occasionally caught in nearshore waters, the sportfishery for big game fishes did not get underway until blue marlin *(Makaira nigricans)* and white marlin *(Tetrapturus albidus)* were discovered in offshore waters of the Gulf of Mexico by the research vessel *Oregon* of the U.S. Fish and Wildlife Service (Bullis, 1955). Impressive longline catches of blue marlin and white marlin had been made off South Pass at the mouth of the Mississippi River by the crew of the *Oregon*. Following this discovery, a sportfishery for big game fishes began off the Mississippi delta. The first catches of white marlin, blue marlin, and yellowfin tuna *(Thunnus albacares)* by sportfishermen were made off South Pass in June, 1956 (Kalman, 1970).

In the years that followed, the sportfishery for billfishes expanded, so that sportboats from Pensacola, Destin, and Panama City (all ports in northwest Florida) were also participating in the sportfishery. In Destin, sailfish had been caught as early as 1955, but the first white marlin was landed in 1959 and the first blue marlin in 1962. In 1964, at least 33 marlin (blue and white combined) and 98 sailfish had been caught. The early history and development of the sportfishery for billfishes in the northeastern Gulf of Mexico was reported by Siebenaler (1965).

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[1] NOAA, National Marine Fisheries Service, Gulf Coastal Fisheries Center, Panama City Laboratory, Panama City, FL 32401

[2] NOAA, National Marine Fisheries Service, Southeast Fisheries Center, Miami, FL (present duty station, Panama City Laboratory, Panama City, FL 32401).

Boats of various characteristics are used in the sportfishery. Boat lengths vary from less than 20 ft (6.1 m) to over 60 ft (18.3 m). Either gas or diesel engines are used. The number of lines fished from a boat may vary from two to four; however, most boats fish four lines, the two outer lines generally trailing out from outriggers. Most boats also use "teasers," devices trolled at short distances astern to attract fish. Soft drink bottles, bunched-up strands of colored nylon or other synthetic material, and other devices are used as teasers. Generally, two, one on each side of the stern, are used.

Analyses of data on sportfisheries for billfishes are rare, probably owing to lack of record keeping. The best analysis made to date was of the sportfishery for sailfish off Kenya during 1958-68 by Williams (1970). Data from a sportfishery for billfishes combined with data from the commercial fishery were used by Strasburg (1970) for his analysis of the Hawaiian fishery. A report to anglers by Nakamura (1971) presented the results of an analysis of data kept by the New Orleans Big Game Fishing Club for the area off the Mississippi River Delta during the period 1966-70. A subsequent similar report for anglers for the year 1971 was expanded to include the northwest Florida area (Nakamura and Rivas, 1972).

Our report presents the results of studies made on the sportfishery for billfishes in 1971 in the northeastern Gulf of Mexico. This study was initiated in 1970 at the Panama City Laboratory (known then as the Eastern Gulf Marine Laboratory) of the National Marine Fisheries Service in Panama City, Florida. Much data were provided to us by sportsmen and boat captains and members of big game fishing clubs and charter boat associations in New Orleans, Mobile, Pensacola, Destin, and Panama City.

SOURCE AND TREATMENT OF DATA

Two distinct areas were fished (Fig. 1). One was the area off South Pass at the mouth of the Mississippi River. This was fished by members of the New Orleans Big Game Fishing Club. The other was the area offshore of northwest Florida. This was fished by boats out of Pensacola (both the Mobile Big Game Fishing Club and the Pensacola Big Game Fishing Club), Destin (Destin Charter Boat Association), and Panama City (Panama City Charter Boat Association). Because these two areas did not overlap, we separated their respective data in our analyses.

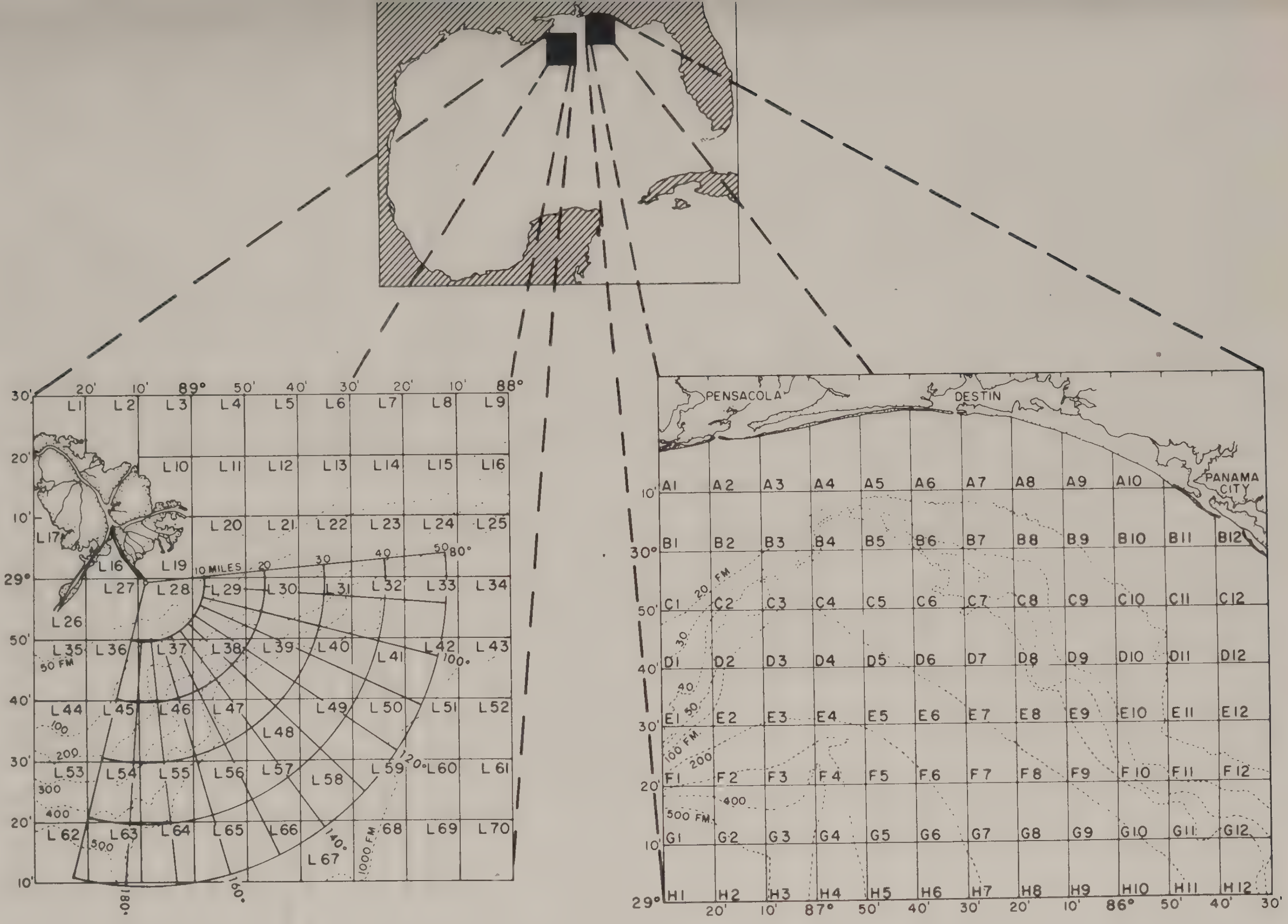
The data supplied by sportfishermen and boat captains were recorded on logs (Fig. 2). The New Orleans Big Game Fishing Club had a chart of the South Pass area on the reverse side of its logs, while the other clubs and associations had a chart of the northwest Florida area on the reverse side of their logs.

The charts of the two areas were divided into 10-minute squares (Fig. 1). Each square was alphabetically and numerically labeled, so that locations of fish sightings and catches could easily be identified. Bottom contour lines were also drawn on the charts. The New Orleans Big Game Fishing Club also added compass headings on its chart. In most instances, the anglers drew their tracks from the start to the end of fishing on the charts and marked the locations of fish sightings along their tracks.

The kinds of data recorded on the logs (Fig. 2) included dates and hours of fishing; areas fished; locations and times of raises, hookups, and catches by species; baits used; water color; surface conditions; and boat characteristics. Morphometric and biological data were obtained on specimens after obtaining permission from the angler or boat captain. The only biological data presented in this report are sex ratios. The morphometric data are presented in another paper (Lenarz and Nakamura, 1974).

Our analyses were made for blue marlin, white marlin, and sailfish. Data for all three plus unidentified billfish were combined for billfishes in general. In some instances, we made analyses only for total billfishes, as data by species involved very small numbers, or zeros.

Three distinct events occur while billfishing: first, a fish is raised, that is, a billfish comes up to a bait from below, or comes over to a bait from a lateral zone, and while the fish may investigate one or several of the offered baits, it may or may not take one; second, the fish may be hooked, and it may be fought for varying lengths of time, and subsequently, either lost or boated; and third, the fish


PENSACOLA
DESTIN
PANAMA CITY
10 MILES
20 FM
30
40
50
100 FM
200
400
500 FM
50 FM
100
200
300
400
500
1000 FM
80°
100°
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140°
160°
180°
89°
88°
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29°
20'
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40'
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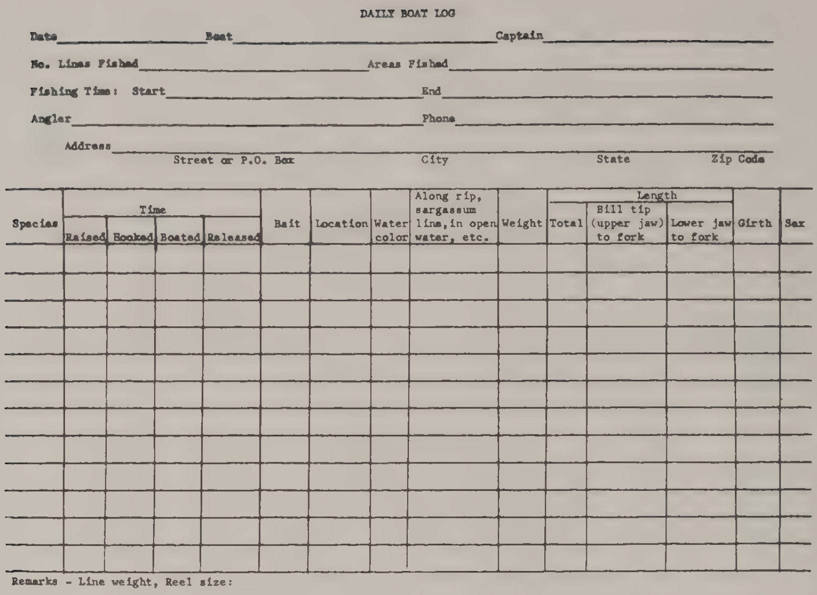
L1 L2 L3 L4 L5 L6 L7 L8 L9
L10 L11 L12 L13 L14 L15 L16
L17 L19 L20 L21 L22 L23 L24 L25
L16 L26 L27 L28 L29 L30 L31 L32 L33 L34
L35 L36 L37 L38 L39 L40 L41 L42 L43
L44 L45 L46 L47 L48 L49 L50 L51 L52
L53 L54 L55 L56 L57 L58 L59 L60 L61
L62 L63 L64 L65 L66 L67 L68 L69 L70
A1 A2 A3 A4 A5 A6 A7 A8 A9 A10
B1 B2 B3 B4 B5 B6 B7 B8 B9 B10 B11 B12
C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12
D1 D2 D3 D4 D5 D6 D7 D8 D9 D10 D11 D12
E1 E2 E3 E4 E5 E6 E7 E8 E9 E10 E11 E12
F1 F2 F3 F4 F5 F6 F7 F8 F9 F10 F11 F12
G1 G2 G3 G4 G5 G6 G7 G8 G9 G10 G11 G12
H1 H2 H3 H4 H5 H6 H7 H8 H9 H10 H11 H12

Figure 1.—The two fishing areas in the northeastern Gulf of Mexico.



DAILY BOAT LOG

Date Boat Captain

No. Lines Fished Areas Fished

Fishing Time: Start End

Angler Phone

Address

Street or P.O. Box City State Zip Code

Species	Time				Bait	Location	Water color	Along rip, sargassum line, in open water, etc.	Weight	Length			Girth	Sex
	Raised	Hooked	Boated	Released						Total	Bill tip (upper jaw) to fork	Lower jaw to fork		

Remarks - Line weight, Reel size:

Figure 2.—Daily boat log used by big game fishermen in the northeastern Gulf of Mexico.

is boated, that is, it is either brought aboard, or brought up to the boat and released.

In determining relative abundance, the number-of-fish-RAISED-per-hour-of-fishing (raises-per-hour) was used as an index in most instances rather than the number-of-fish-CAUGHT-per-hour-of-fishing (catch-per-hour). We felt that the former was much less affected by the skill of the angler than the latter. If a fish were hooked and lost, it would not be included in the catch-per-hour, but it would in the raises-per-hour. Use of raises-per-hour offered an additional advantage: much more data were available. The disadvantages were the possibility of the same fish being raised more than once, and the possibility of misidentification of the species. We felt that the advantages outweighed the disadvantages.

In determining the number of hours fished, we deducted the time spent fighting a fish. Whenever a fish is hooked, all lines except the one with the hooked fish are reeled in. Thus, if a fish were hooked at 1000 h and boated (or lost, or released) at 1130 h, 1½ h were deducted from the total fishing time, which was derived by subtracting the time the lines were put in the water from the time the lines were pulled out preparatory to returning to port.

The number of lines trolled was not considered, as we felt that this factor had little influence on whether or not a fish was raised. Most boats trolled four lines, although a few of the small boats trolled only two or three lines.

Sailfish were often caught while trolling inshore for king mackerel *(Scomberomorus cavalla)*, Spanish mackerel *(Scomberomorus maculatus)*, and cobia *(Rachycentron canadum)*. Since the fishing method for these smaller game fishes is different from big game fishing, all sailfish caught and the effort expended for this type of fishing were disregarded.

Where data were insufficient or lacking to permit the use of raises-per-hour, other indices of relative abundance were used. Catch-per-hour, hookups-per-day, and percentages were used in some of our analyses. True estimates of abundance could not be obtained. Therefore, the term *abundance* when used in this paper refers to relative abundance. Data for years prior to 1971 for South Pass are presented for historical comparison in some tables of this paper. These data were taken from Nakamura's mimeographed report (1971).

We believe that we obtained data from more than 90% of the total effort expended in offshore sportfishing for billfishes in the eastern half of the Gulf of Mexico (from the mouth of the Mississippi River to the west coast of Florida). The amount of billfishing occurring between Panama City, Florida, and the southern tip of Florida is negligible (less than 5% of the total in the eastern half of the Gulf of Mexico, we believe). Billfishing other than from South Pass and the three ports in northwest Florida (Pensacola, Destin, and Panama City) in the northeastern gulf coast is also negligible (also less than 5% of the total in the eastern half of the Gulf of Mexico).

We do not have any measures of the reliability of the data provided by the sportfishermen. We can report that almost all the sportfishermen appeared to be very sincere and genuinely interested in helping and cooperating with us. Data that were obviously erroneous were discarded; data that were questionable were disregarded.

Further details of the method of analyses are presented in the following sections of this paper.

CATCH, RAISE, AND EFFORT STATISTICS

The number of billfishes raised, hooked, and boated by months for both the South Pass and northwest Florida areas are presented in Tables 1 and 2. Although a few trips were taken as early as April, the fishing season essentially lasts from May through October.

If the percentages at the bottom of Tables 1 and 2 may be considered as indices of the proficiency of anglers, an obviously significant difference can be seen between the two areas for white marlin. In the South Pass area, only 37.1% of the 167 raised white marlin were hooked; of the 167, only 10.8% were boated; and of the 62 hooked white marlin, 29.0% were boated. Comparable percentages for white marlin in the northwest Florida area were 61.0, 39.0, and 63.9. Little difference between areas is seen for the other two species.

Table 1.—Billfishes raised (R), hooked (H), and boated (B, includes releases) off South Pass, 1971.

Species	Blue Marlin			White Marlin			Sailfish			Unidentified Billfish	
Event	R	H	B	R	H	B	R	H	B	R	H
Apr.	0	0	0	1	1	0	0	0	0	0	0
May	13	9	6	6	2	0	0	0	0	2	2
June	32	15	8	18	9	4	4	3	2	0	0
July	60	31	9	40	17	6	12	7	3	0	0
Aug.	68	25	9	86	27	8	32	23	16	5	0
Sept.	26	12	2	11	4	0	2	1	0	0	0
Oct.	4	1	0	5	2	0	2	1	0	0	0
Total	203	93	34	167	62	18	52	35	21	7	2
% of Raised		45.8	16.7		37.1	10.8		67.3	40.4		28.6
% of Hooked			36.6			29.0			60.0		

Table 2.—Billfishes raised (R), hooked (H), and boated (B, includes releases) off northwest Florida, 1971.

Species	Blue Marlin			White Marlin			Sailfish			Unidentified Billfish	
Event	R	H	B	R	H	B	R	H	B	R	H
May	2	2	1	4	3	1	2	2	1	0	0
June	51	37	18	52	29	13	38	16	11	1	1
July	52	32	8	289	167	104	114	68	49	10	2
Aug.	79	44	23	212	126	84	194	123	81	15	1
Sept.	42	18	2	40	27	20	362	197	123	2	0
Oct.	63	36	13	85	64	44	98	49	32	4	2
Total	289	169	65	682	416	266	808	455	297	32	6
% of Raised		58.5	22.5		61.0	39.0		56.3	36.8		18.8
% of Hooked			38.5			63.9			65.3		

Although we are unable to provide any factual information to explain the greater percentages of hooked and boated white marlin in the northwest Florida area, we can provide some conjecture. One is that many more boats from northwest Florida are captained by professional fishermen (charter boat captains), whereas most of the boats from South Pass are captained by sportfishermen. Second, white marlin are much more abundant in northwest Florida, thus providing more experience with this species to the fishermen from this area.

A comparison of the catch, effort, and catch-per-hour of billfishes in the two areas is presented in Tables 3 and 4. Catch-per-hour is used here, as data on raises were not available prior to 1971.

For South Pass, the total number of billfishes (73) caught in 1971 was the second lowest. Fewer white marlin were caught in 1971 than any previous year of record. The catch-per-hour indicated that 1971 was in general a below average year: about average for blue marlin, lowest of any year for white marlin, and below average for sailfish.

More than twice as much effort was expended off northwest Florida (7,890 h) than off South Pass

Table 3.—Catch, effort, and catch-per-hour of billfishes off South Pass, 1966-71.

Year	1966	1967	1968	1969	1970	1971
Number caught						
Blue marlin	57	42	72	25	19	34
White marlin	151	113	95	38	22	18
Sailfish	42	46	30	12	20	21
Total hours fished	—	2,339	5,801	4,139	2,603	3,217
Catch-per-hour						
Blue marlin	—	0.018	0.012	0.006	0.007	0.011
White marlin	—	0.048	0.016	0.009	0.008	0.006
Sailfish	—	0.020	0.005	0.003	0.008	0.007

Table 4.—Catch, effort, and catch-per-hour of billfishes off northwest Florida, 1971.

Port	Pensacola	Destin	Panama City	All Three Ports
Number caught				
Blue marlin	17	43	5	65
White marlin	41	195	30	266
Sailfish	18	265	14	297
Total hours fished	1,834	5,425	631	7,890
Catch-per-hour				
Blue marlin	0.009	0.008	0.008	0.008
White marlin	0.022	0.036	0.048	0.034
Sailfish	0.010	0.049	0.022	0.038

(3,217 h) in 1971. Of the effort expended in northwest Florida, boats from Destin accounted for 69% of the total.

Blue marlin were more abundant off South Pass than off northwest Florida in 1971, as indicated by the catch-per-hour (0.011 versus 0.008), whereas white marlin (0.034 versus 0.006) and sailfish (0.038 versus 0.007) were more abundant off northwest Florida (Tables 3 and 4).

When raises-per-hour were compared (Table 5), the same conclusions of relative abundance were reached. The reciprocals of raises-per-hour, that is, hours-to-raise-1-fish, are also presented in Table 5. Fewer hours were spent trolling off South Pass to raise a blue marlin (15.9 versus 27.0), whereas fewer hours were spent off northwest Florida for white marlin (11.6 versus 19.2) and for sailfish (9.8 versus 62.5).

SIZE AND SEX RATIO

The range of weights and the average weights for each species for the two areas are presented in Tables 6 and 7. The largest blue marlin, 492.0 lb (223.6 kg), caught in 1971 was off South Pass; the largest white marlin, 86.0 lb (39.1 kg), and the largest sailfish, 67.0 lb (30.5 kg), were caught off northwest Florida by boats from Destin. For South Pass, the range and average for blue marlin was not unusual; neither was the average for sailfish. However, the largest specimens of white marlin, 84.0 lb (38.2 kg), and of sailfish, 58.5 lb (26.6 kg), were smaller than the largest specimens of each species caught in any previous year of record. And the average weight of white marlin, 61.3 lb (27.9 kg), in 1971 was the highest ever.

Females of all three species of billfishes dominated the catches. Sex ratios for the years 1967-71 for South Pass and for 1971 for northwest Florida are presented in Table 8. Only those specimens were examined for which permission was granted.

The predominance of females in the blue marlin caught off northeastern Gulf of Mexico is contrary to that in blue marlin caught off Puerto Rico and the Virgin Islands (Erdman, 1962, 1968). There, an equal male-female ratio was found during July and August, the months of spawning. In September, the ratio changed to 4.5:1 in favor of males. The annual average for catches of blue marlin from 1950-66 was 4:1 in favor of males.

Sex ratios of white marlin caught off New Jersey and Maryland, like those caught in the northeastern Gulf of Mexico, also favored females. In 1959, the male-female ratio was 1:2.4; in 1960, it was 1:1.2 (de Sylva and Davis, 1963).

RELATIVE ABUNDANCE BY TIME

The number of raises per hour was determined for weekly periods and hourly periods. Each week began on a Wednesday and ended on the following

Table 5.—Relative abundance of billfishes in the northeastern Gulf of Mexico, 1971.

Area	South Pass	Northwest Florida
Raises-per-hour		
Blue marlin	0.063	0.037
White marlin	0.052	0.086
Sailfish	0.016	0.102
Hours-to-raise-1-fish		
Blue marlin	15.9	27.0
White marlin	19.2	11.6
Sailfish	62.5	9.8

able 6.—Weights in pounds (kilograms in parentheses) of billfishes caught off South Pass, 1966-71.

ear	1966	1967	1968	1969	1970	1971
lue marlin						
Range	65.0-565.0	62.0-565.0	77.0-465.0	133.5-686.0	90.5-535.0	83.0-492.0
	(29.5-256.8)	(28.2-256.8)	(35.0-211.4)	(60.7-311.8)	(41.1-243.2)	(37.7-223.6)
Average	219.7	299.0	252.0	273.4	273.7	279.4
	(99.9)	(135.9)	(114.5)	(124.3)	(124.4)	(127.0)
White marlin						
Range	29.0-100.0	30.0-134.0	32.0-85.0	39.0-86.0	36.0-85.0	33.0-84.0
	(13.2-45.5)	(13.6-60.9)	(14.5-38.6)	(17.7-39.1)	(16.4-38.6)	(15.0-38.2)
Average	48.9	46.5	50.0	59.6	53.3	61.3
	(22.2)	(21.1)	(22.7)	(27.1)	(24.2)	(27.9)
ailfish						
Range	27.0-80.0	25.0-75.0	36.0-78.0	35.0-66.0	25.0-67.0	37.0-58.5
	(12.3-36.4)	(11.4-34.1)	(16.4-35.5)	(15.9-30.0)	(11.4-30.5)	(16.8-26.6)
Average	45.5	46.4	40.1	51.7	40.3	43.1
	(20.7)	(21.1)	(18.2)	(23.5)	(18.3)	(19.6)

Tuesday, so that a weekend was not split. Each hour began on the hour and ended 1 min before the next hour.

The results of our analyses of raises per hour by weekly periods are presented in Figure 3. For the South Pass area, blue marlin were most abundant in late September; white marlin were most abundant in early August; sailfish did not appear to be especially abundant during any week (only 52 sailfish were raised during the entire year). For the northwest Florida area, the highest peak in relative abundance of blue marlin was the week 29 Sept. to 5 Oct., but the weekly variations were not as great as for the other two species; for white marlin the pronounced period of abundance was in mid-July; sailfish were especially abundant during the latter half of September.

Several prominent differences in raises-per-hour by weekly periods are evident between the two areas (Fig. 3). For example, peaks of abundance for white marlin and sailfish in the South Pass area are not as pronounced as in the northwest Florida area. Also, blue marlin are more abundant off South Pass, whereas white marlin and sailfish are more abundant off northwest Florida.

The results of our analyses of raises-per-hour by time of day are presented in Figure 4. The numbers of fish raised and numbers of hours trolled are tabulated in Tables 9 and 10. The early morning (0600 h) peak for South Pass and late afternoon (1800 h) peak for northwest Florida should be regarded cautiously, as these are based on small amounts of effort.

The patterns of abundance by time of day for each species in each area (Fig. 4) show a pre-noon and a post-noon peak, with some showing two pre-noon peaks (blue marlin and white marlin off northwest Florida) and some showing two post-noon peaks (white marlin off northwest Florida, blue marlin and white marlin off South Pass). All show a midday drop in abundance.

When data for all three species from both areas are combined (Fig. 5), a multimodal distribution is seen, the most prominent peak at 1000 h and smaller peaks at 1400 and 1800 h.

Table 7.—Weights in pounds (kilograms in parentheses) of billfishes caught off northwest Florida, 1971.

Port	Pensacola	Destin	Panama City	All Three Ports
Blue marlin				
Range	32.0-481.5	46.0-426.0	128.0-253.0	32.0-481.5
	(14.5-218.9)	(20.9-193.6)	(58.2-115.0)	(14.5-218.9)
Average	266.9	180.7	189.1	207.5
	(121.3)	(82.1)	(86.0)	(94.3)
White marlin				
Range	40.5-83.5	31.0-86.0	42.0-80.0	31.0-86.0
	(18.4-38.0)	(14.1-39.1)	(19.1-36.4)	(14.1-39.1)
Average	56.0	54.9	52.9	54.8
	(25.5)	(25.0)	(24.0)	(24.9)
Sailfish				
Range	30.5-43.0	5.5-67.0	11.0-50.0	5.5-67.0
	(13.9-19.5)	(2.5-30.5)	(5.0-22.7)	(2.5-30.5)
Average	36.8	37.9	38.1	37.6
	(16.7)	(17.2)	(17.3)	(17.1)

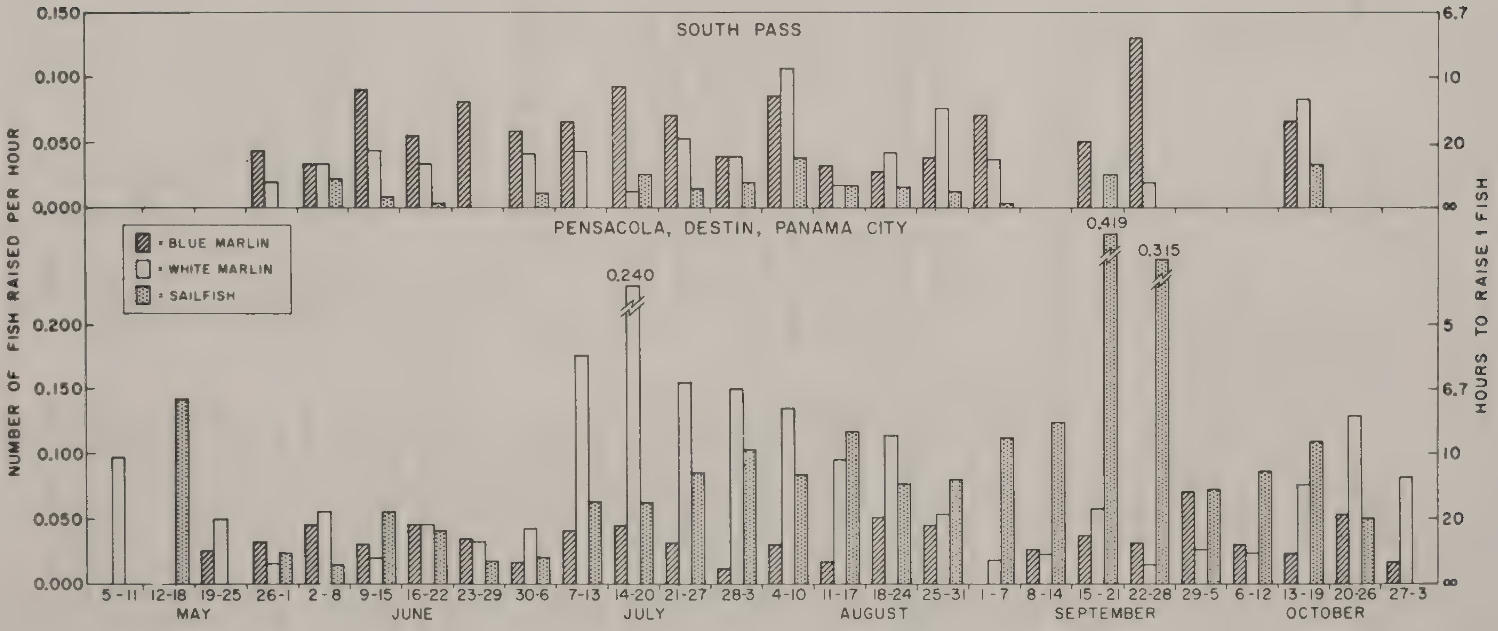


Figure 3.—Relative abundance of billfishes by weekly periods for South Pass and northwest Florida, 1971.

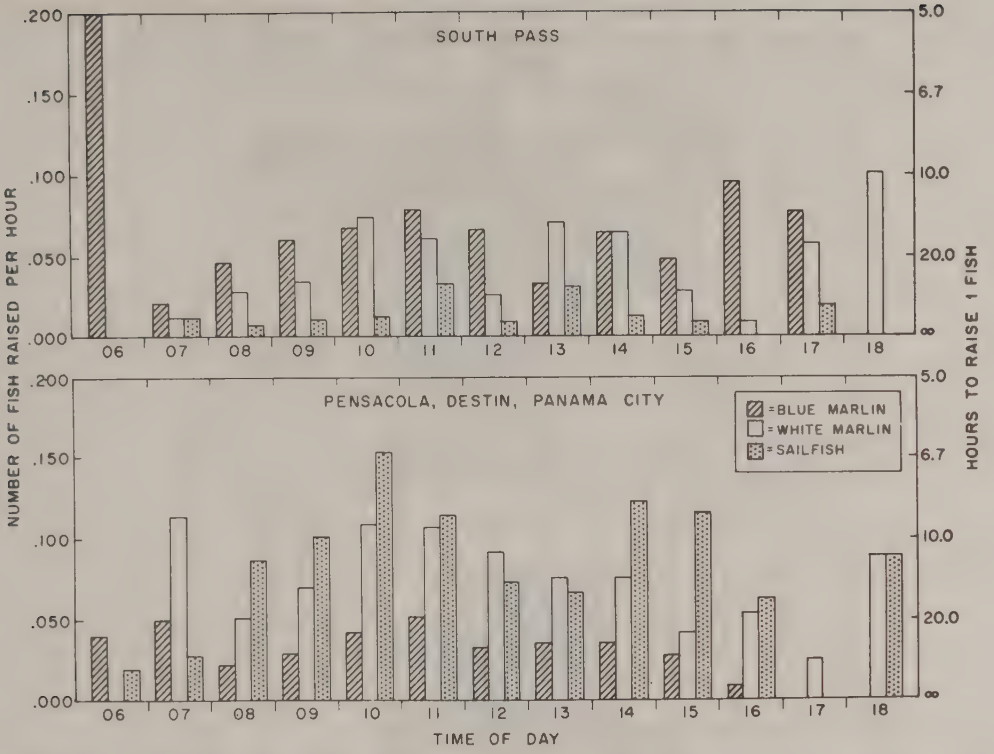


Figure 4.—Relative abundance of billfishes by time of day for South Pass and northwest Florida, 1971.

RELATIVE ABUNDANCE BY TEN-MINUTE SQUARES

To determine the relative abundance of billfishes by ten-minute squares, the data were analyzed by calculating the number of fish raised per hour of fishing within each square during biweekly periods. For South Pass, the biweekly periods were begun on 26 May and were ended 28 September. Effort before and after this period was very low and sporadic. For northwest Florida, the biweekly periods were begun on 26 May and were ended on 9 November for the same reason.

The data for all species combined for the two areas are illustrated in Figures 6 and 7. The data for

Table 8.—Sex ratios of billfishes caught off South Pass, 1967-71, and off northwest Florida, 1971 (no. of males versus no. of females in parentheses).

Area	South Pass					NW Florida
Year	1967	1968	1969	1970	1971	1971
Blue marlin	1:5.6 (5:28)	1:7.7 (6:46)	1:4.8 (4:19)	1:8.0 (2:16)	1:3.3 (7:23)	1:3.1 (12:37)
White marlin	1:2.3 (20:46)	1:3.9 (15:59)	1:6.2 (4:25)	1:4.0 (4:16)	1:4.0 (3:12)	1:4.3 (28:120)
Sailfish	1:2.0 (10:20)	1:3.6 (5:18)	1:8.0 (1:8)	1:1.4 (8:11)	1:2.4 (5:12)	1:2.5 (63:159)

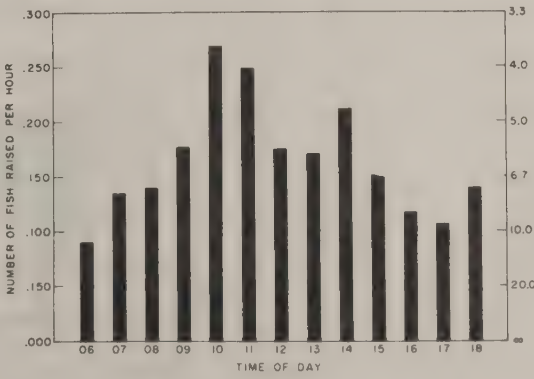
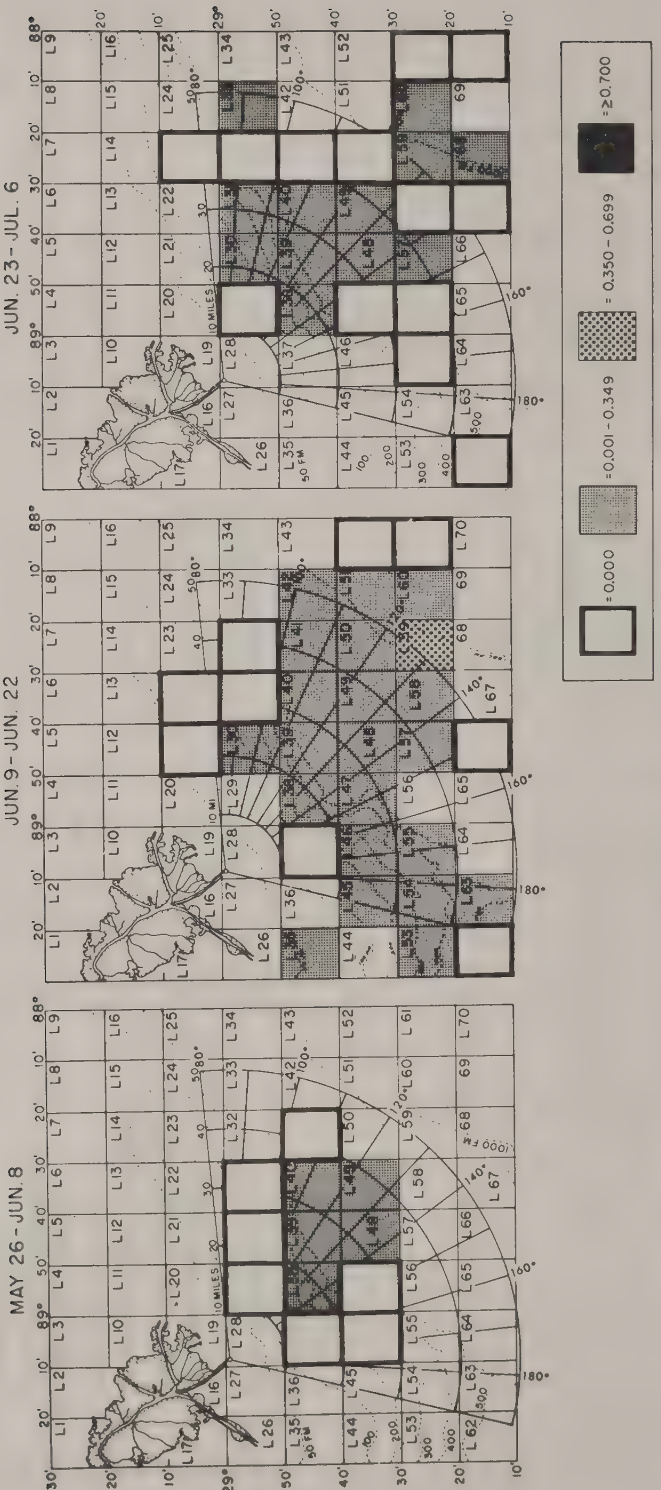


Figure 5.—Relative abundance of billfishes by time of day, South Pass and northwest Florida combined, 1971.



MAY 26 - JUN. 8
JUN. 9 - JUN. 22
JUN. 23 - JUL. 6
= 0.000
= 0.001 - 0.349
= 0.350 - 0.699
= ≥0.700
10 MILES
50 FM
1000 FM
88°
89°
29°

Figure 6.—Relative abundance of all billfishes by ten-minute squares for biweekly periods, South Pass, 1971.

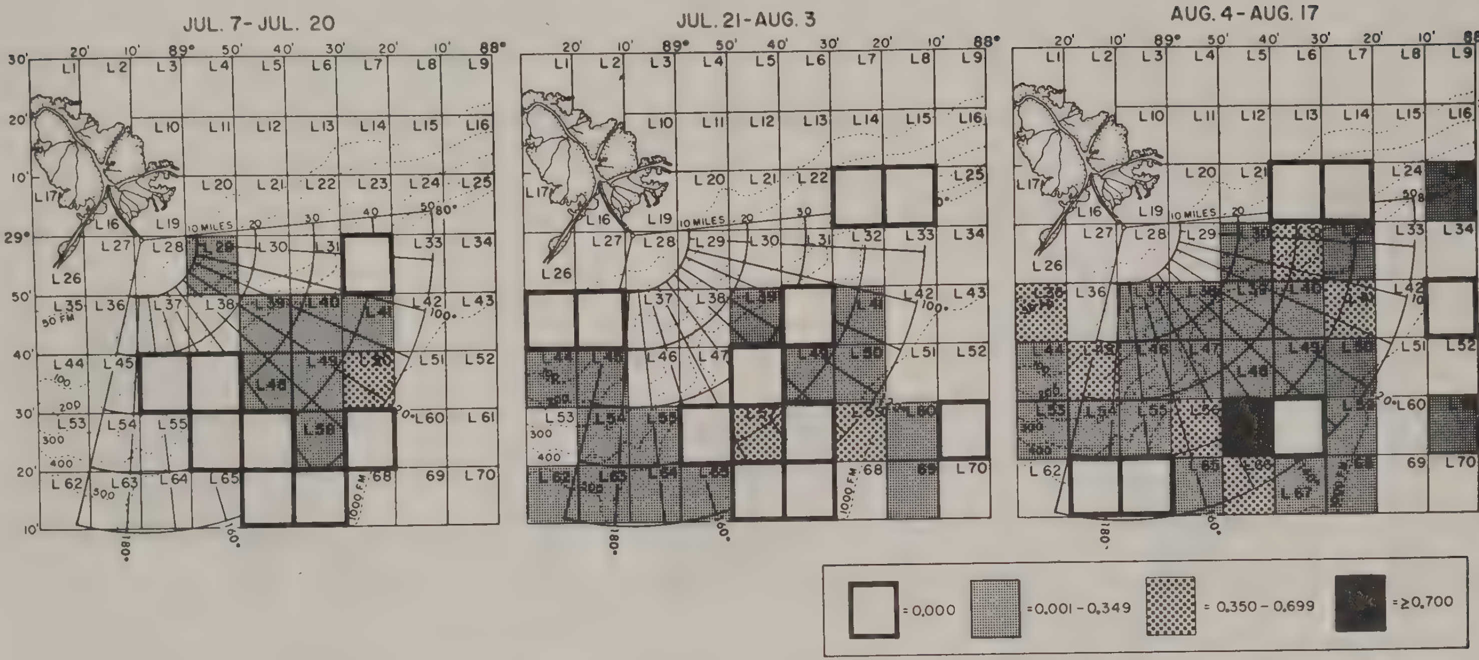

JUL. 7-JUL. 20
JUL. 21-AUG. 3
AUG. 4-AUG. 17
= 0.000
=0.001-0.349
= 0.350-0.699
=≥0.700
10 MILES
1000 FM
160°
180°

Figure 6.—Relative abundance of all billfishes by ten-minute squares for biweekly periods, South Pass, 1971.—continued.

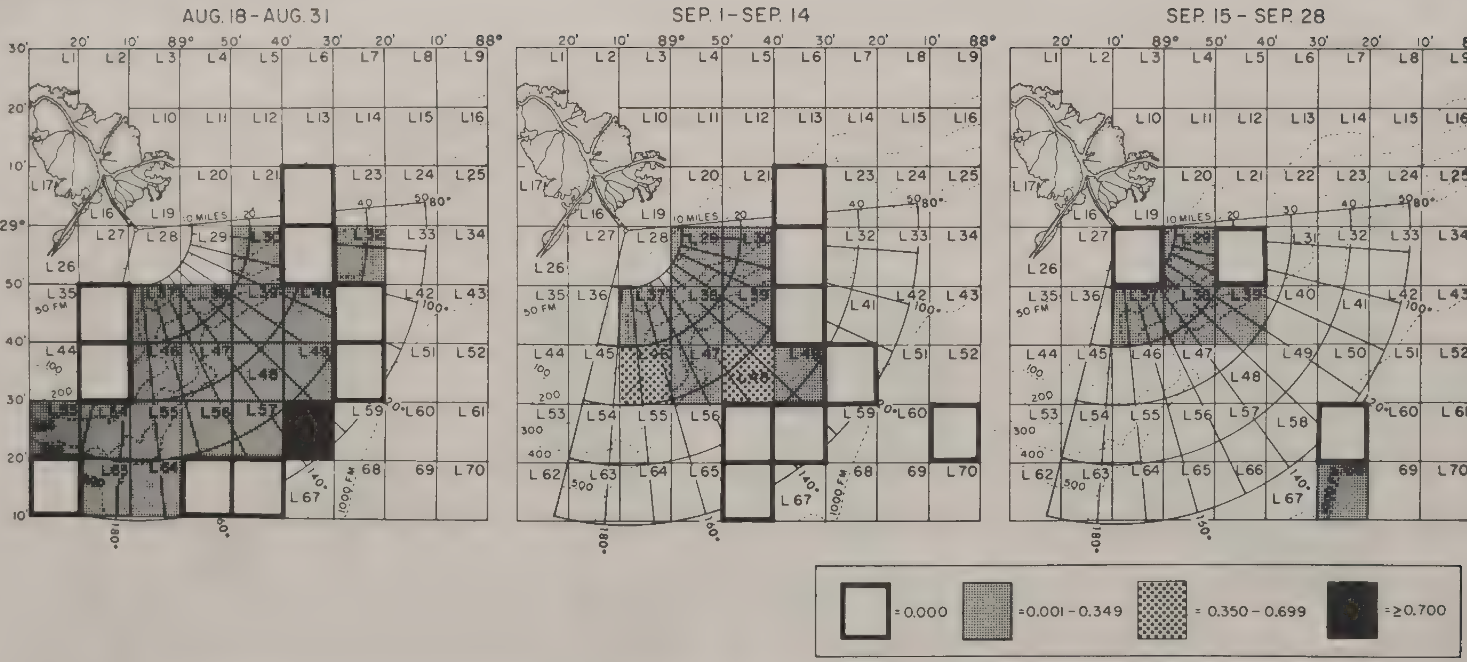

AUG. 18 - AUG. 31
SEP. 1 - SEP. 14
SEP. 15 - SEP. 28
10 MILES
50 FM
1000 FM
= 0.000
= 0.001 - 0.349
= 0.350 - 0.699
= ≥0.700

Figure 6.—Relative abundance of all billfishes by ten-minute squares for biweekly periods, South Pass, 1971.—continued.

each species have not been presented, as no particular ten-minute square was consistently high in abundance.

The biweekly periods 9 June-22 June and 4 Aug.-17 Aug. for South Pass, and 23 June-6 July and 4 Aug.-17 Aug. for northwest Florida were the periods with the widest dispersement of fishing effort. Because of this, probably, these periods showed the widest dispersement of billfishes.

The "Nipple," named for the curvature of the 100-fathom line in square C3 (Fig. 7) off northwest Florida, is a favorite fishing site for big game fishermen. It was not especially abundant with billfishes. July was the month during which billfishes were most abundant in the "Nipple" area. As the season progressed, most of the high-abundance squares appeared in the southern sectors in and to the sides of the De Soto Canyon in squares F3, F4, G3, and G4 (Fig. 7).

EFFECT OF WATER COLOR

Water color where billfishes were raised was categorized as blue, blue-green, and green. The few reports stating water color as "dirty water" were excluded.

The results indicate that the bluer the water, the greater the abundance of all three species. As shown in Table 11, the number of fish raised per hour decreased and the number of hours to raise a fish increased from blue to blue-green and again from blue-green to green for each species, except for sailfish. In South Pass, sailfish abundance was about equal in blue-green and green waters and least in blue water, whereas in northwest Florida, it was about equal in blue and blue-green waters and least in green.

EFFECT OF SURFACE CONDITION

Visible surface conditions under which billfishes were raised were categorized as open water, lines or rips, scattered grass, grass patches, and others. The term open water was selected for surface conditions when tide lines or rips, sargassum, and floating objects were not present. Tide rips, tide lines, and lines of sargassum were classed as lines or rips. When sargassum was scattered over the surface and not in large clumps, the condition was classified as scattered grass. When sargassum appeared in clumps or patches, the term grass patch was used.

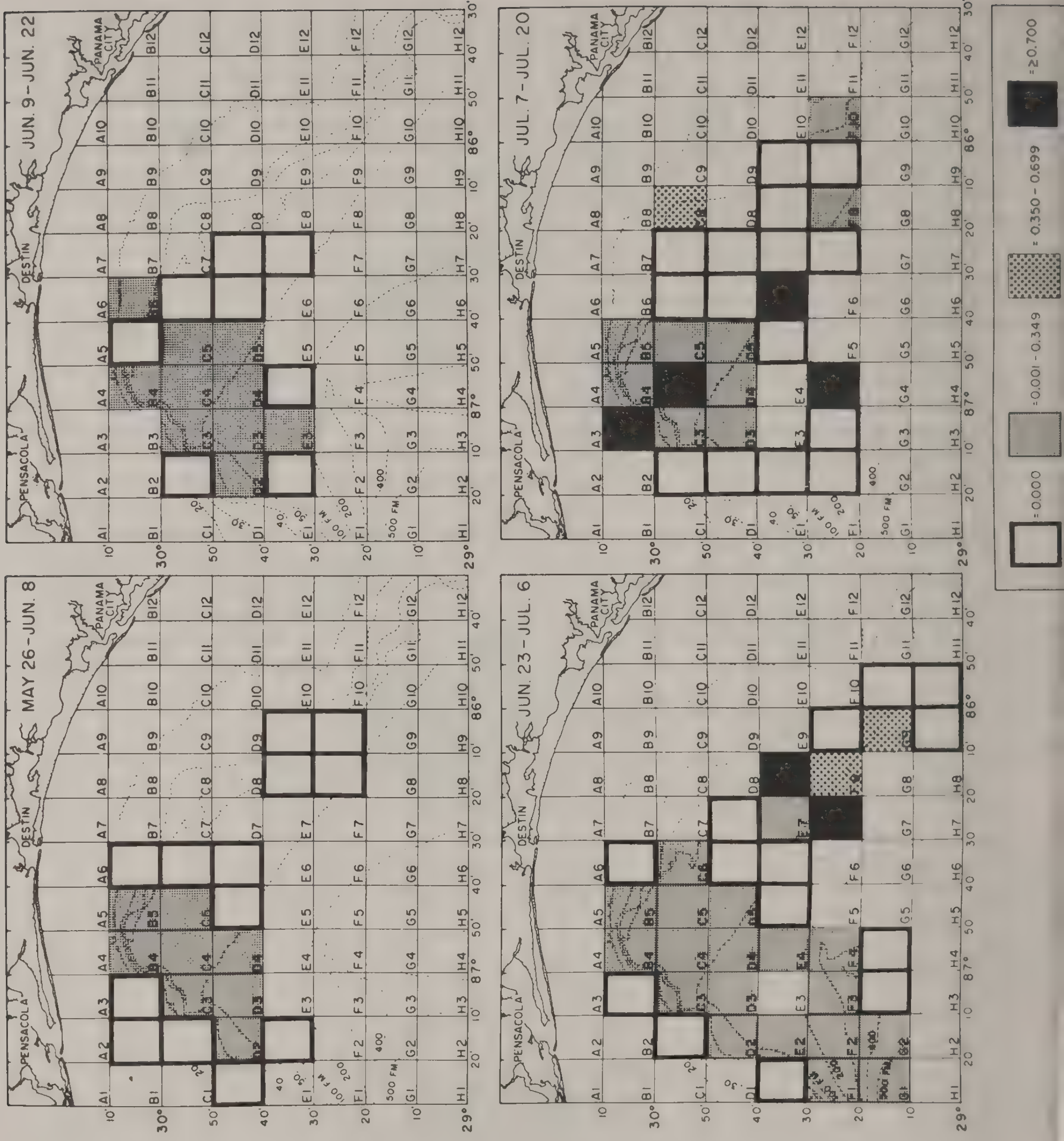
The number of hours fished in each category

Table 9.—Numbers of billfishes raised and hours trolled by time of day, South Pass, 1971.

Time of day	0600-0659	0700-0759	0800-0869	0900-0959	1000-1059	1100-1159	1200-1259	1300-1359	1400-1459	1500-1559	1600-1659	1700-1759	1800-1859
Blue marlin	1	2	13	23	28	34	28	13	22	12	12	4	0
White marlin	0	1	8	13	31	26	11	28	22	7	1	3	1
Sailfish	0	1	2	4	5	14	4	12	4	2	0	1	0
Unidentified billfish	0	0	1	2	2	1	0	0	0	0	0	0	0
All billfish	1	4	24	42	66	75	43	53	48	21	13	8	1
Hours trolled	5.00	94.50	282.50	384.25	418.75	434.25	425.25	400.50	341.75	253.75	126.00	52.75	10.00

Table 10.—Numbers of billfishes raised and hours trolled by time of day, northwest Florida, 1971.

Time of day	0600-0659	0700-0759	0800-0859	0900-0959	1000-1059	1100-1159	1200-1259	1300-1359	1400-1459	1500-1559	1600-1659	1700-1759	1800-1859
Blue marlin	2	7	13	31	48	60	37	39	34	12	1	0	0
White marlin	0	16	30	75	125	124	104	82	72	18	6	1	1
Sailfish	1	4	51	108	176	132	84	72	117	50	7	0	1
Unidentified billfish	1	1	3	3	5	5	5	6	3	3	1	1	0
All billfish	4	28	97	217	354	321	230	199	226	83	15	2	2
Hours trolled	49.75	140.50	587.50	1,069.75	1,143.00	1,150.75	1,128.00	1,074.50	953.50	429.25	111.75	40.75	11.25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JUN. 9 - JUN. 22
JUN. 23 - JUL. 6
JUL. 7 - JUL. 20
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200
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30°
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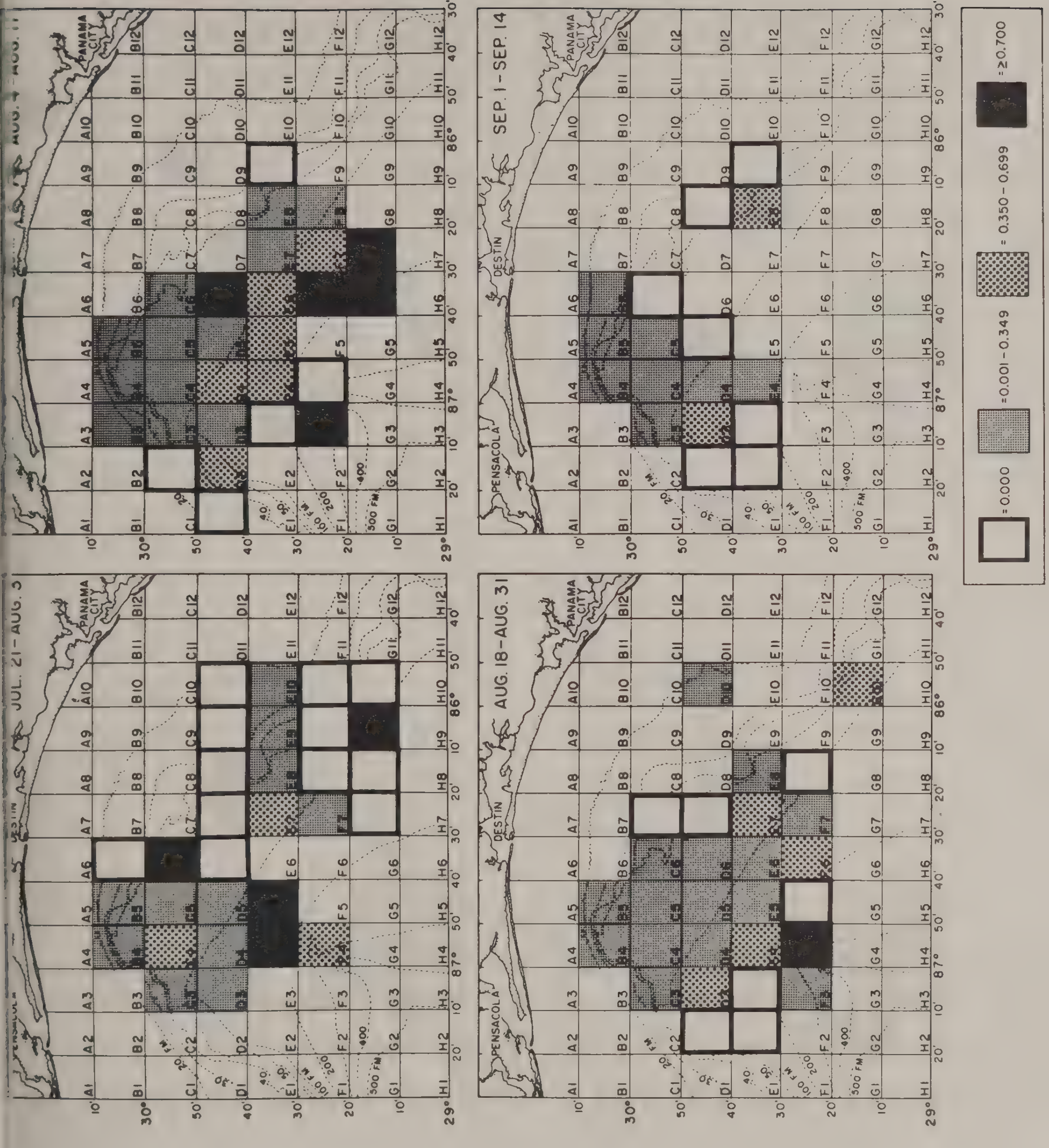
=0.350 - 0.699
≥0.700

Figure 7.—Relative abundance of all billfishes by ten-minute squares for biweekly periods, northwest Florida, 197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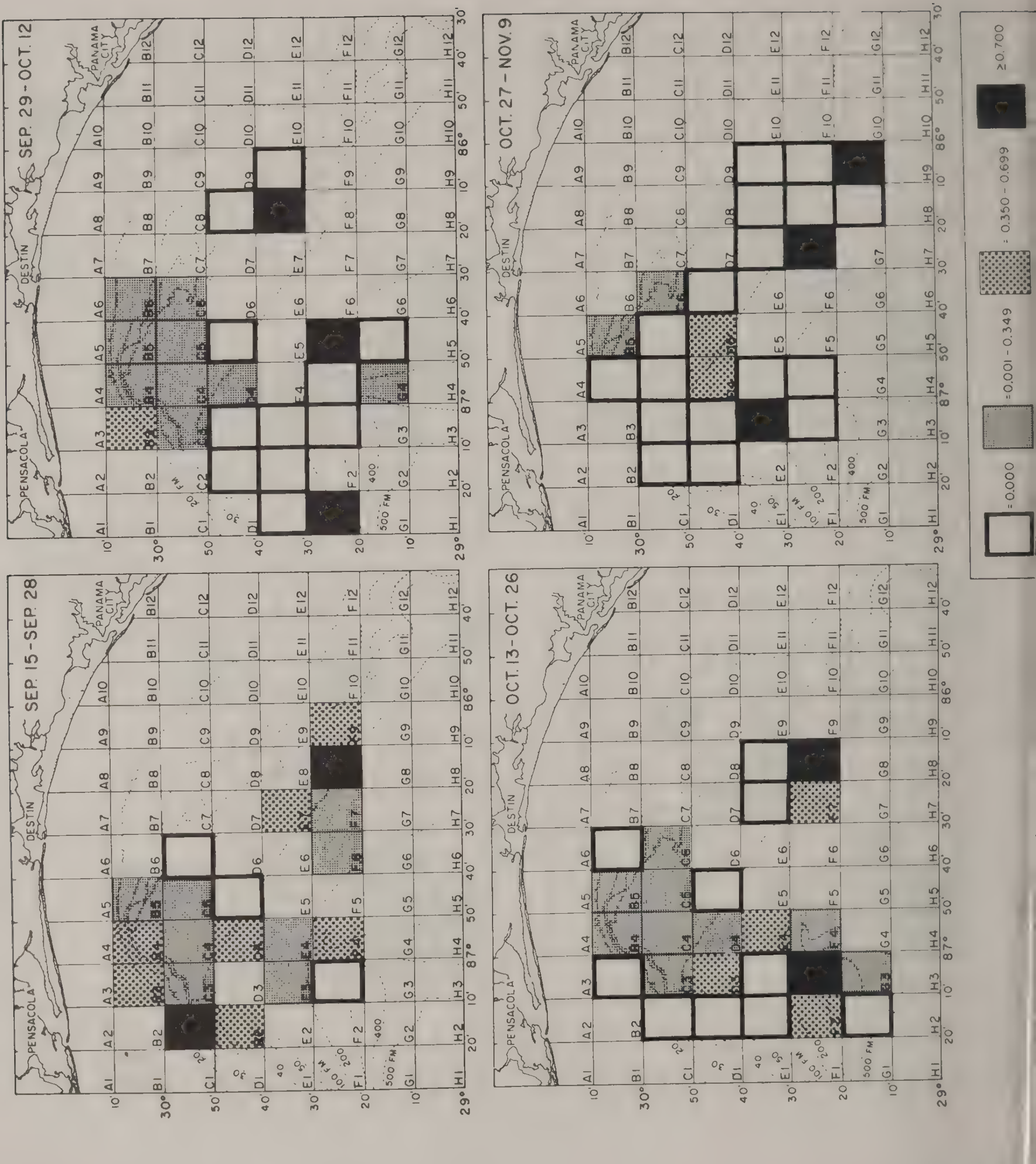
gure 7.—Relative abundance of all billfishes by ten-minute squares for biweekly periods, northwest Florida, 1971.—continued.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87°
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Figure 7.—Relative abundance of all billfishes by ten-minute squares for biweekly periods, northwest Flor
1971.—continued.

Table 11.—Relative abundance of billfishes by water color for South Pass, northwest Florida, and the two areas combined, 1971. (BM=blue marlin, WM=white marlin, SF=sailfish).

Water color	Blue Water			Blue-Green Water			Green Water		
Species	BM	WM	SF	BM	WM	SF	BM	WM	SF
South Pass									
No. of fish raised	72	62	10	80	69	26	36	23	13
No. of hours trolled	877.1	877.1	877.1	1,185.4	1,185.4	1,185.4	653.7	653.7	653.7
Fish raised per hour	0.082	0.071	0.011	0.067	0.058	0.022	0.055	0.035	0.020
Hrs. to raise 1 fish	12.2	14.1	90.1	14.9	17.2	45.5	18.2	28.6	50.0
Northwest Florida									
No. of fish raised	230	489	593	21	58	118	7	6	14
No. of hours trolled	4,554.9	4,554.9	4,554.9	886.5	886.5	886.5	312.5	312.5	312.5
Fish raised per hour	0.050	0.107	0.130	0.024	0.065	0.133	0.022	0.019	0.045
Hrs. to raise 1 fish	20.0	9.3	7.7	41.7	15.4	7.5	45.5	52.6	22.2
Both areas									
No. of fish raised	302	551	603	101	127	144	43	29	27
No. of hours trolled	5,432.0	5,432.0	5,432.0	2,071.9	2,071.9	2,071.9	966.2	966.2	966.2
Fish raised per hour	0.056	0.101	0.111	0.049	0.061	0.070	0.045	0.030	0.028
Hrs. to raise 1 fish	17.9	9.9	9.0	20.4	16.4	14.3	22.2	33.3	35.7

could not be determined from the logs. Therefore, since we could not determine the number of fish raised per hour of trolling, we decided to use the percentage of the total number of fish raised as a measure of relative abundance. The data are presented in Table 12.

As the percentages show, the most productive surface condition off South Pass was along lines or rips. Nearly half of each species was raised along lines or rips. Off northwest Florida, open water was the most productive surface condition, the percentages ranging from 52% to 67%. Open water was second best off South Pass, while scattered grass was second best off northwest Florida. In the scattered grass, grass patches, and others categories, the percentages for blue marlin and white marlin were about equal. Sailfish were twice as abundant along scattered grass off northwest Florida area than off South Pass.

When the data for the two areas were combined, open water appeared as the best condition, scattered grass second, and lines or rips third.

Table 12.—Surface conditions and billfishing off South Pass, northwest Florida, and the two areas combined, 1971. (BM=blue marlin, WM=white marlin, SF=sailfish).

Surface condition	Open Water			Lines or Rips			Scattered Grass			Grass Patches			Others			Total No. Raised		
Species	BM	WM	SF	BM	WM	SF	BM	WM	SF	BM	WM	SF	BM	WM	SF	BM	WM	SF
South Pass																		
No. of fish raised	51	45	14	87	67	23	36	30	10	6	6	1	9	2	0	189	150	48
Percent of total no. raised	27%	30%	29%	46%	45%	48%	19%	20%	21%	3%	4%	2%	5%	1%	—	—	—	—
Northwest Florida																		
No. of fish raised	168	436	406	20	68	31	65	125	322	7	6	17	6	15	6	266	650	782
Percent of total no. raised	63%	67%	52%	8%	11%	4%	24%	19%	41%	3%	1%	2%	2%	2%	1%	—	—	—
Both areas																		
No. of fish raised	219	481	420	107	135	54	101	155	332	13	12	18	15	17	6	455	800	830
Percent of total no. raised	48%	60%	51%	24%	17%	6%	22%	19%	40%	3%	2%	2%	3%	2%	1%	—	—	—

EFFECT OF MOON PHASE

Dates of the moon phases were obtained from the 1971 Nautical Almanac. Because the beginning of each quarter phase did not occur at the same hour (for example, new moon in one month would begin at 2255 h and in the next month at 0949 h), data for a 3-day period for each moon phase were compiled, namely, data for the day before, day of, and day after the beginning of each moon phase. For example, new moon for July began at 0915 h on the 22nd; data for the new moon period for July were obtained for the 21st, 22nd, and 23rd. The data for all species were combined, as data for each species were sparse.

For the period May through October, the data for South Pass and northwest Florida are presented in Table 13. Full moon appeared to be the best period for South Pass, whereas new moon appeared to be the best for northwest Florida. When the data for the two areas were combined, no particular moon phase appeared to be especially favorable.

EFFECT OF BOAT SIZE AND TYPE OF SCREW

For this study, boats were categorized into 10-ft lengths, that is, 10-19 ft long, 20-29 ft long, and so on. Then the numbers of hours fished by boats in each category and the numbers of billfish raised by these boats were compiled. Then the average and the reciprocal, the hours-to-raise-one-billfish, were computed for each boat-length category.

Preliminary examination of some data obtained at tournaments in Pensacola and South Pass seemed to indicate that larger boats were more successful. When the South Pass data for the entire year were analyzed, the results still indicated that this was so. As shown in Table 14, the raises-per-hour increased with boat size, and conversely, the hours-to-raise-one-billfish decreased with boat size.

However, when the data for the three Florida ports were combined, as shown in Table 14, the results were not so clear. Results from combining the data for South Pass and the Florida areas did not allow us to conclude that larger boats were more successful.

When the data in Table 14 were broken down by species, no trends were evident. We could not conclude that boat size had any effect on success in raising fish.

Another aspect we examined was the effect of single and twin screws of a boat. For this analysis, the only set of data providing sufficient information was that for the 40-49 ft boats in Destin. The results showed that 40-49 ft boats with twin screws were more successful than 40-49 ft boats with single screw for each species of billfish. The data are summarized in Table 15. More data are needed to corroborate these results, especially with boats of different sizes.

BAIT PREFERENCE

The number of hours fished with the various kinds of bait could not be determined with our data.

Table 13.—Relative abundance of billfishes by moon phase off South Pass, northwest Florida, and the two areas combined, 1971.

Moon phase	New Moon	First Quarter	Full Moon	Last Quarter
South Pass				
No. hrs. trolled	721.3	99.2	742.9	113.5
No. billfish raised	77	16	153	7
Fish raised per hour	0.107	0.161	0.206	0.062
Hrs. to raise 1 fish	9.3	6.2	4.9	16.1
Northwest Florida				
No. hrs. trolled	842.6	809.8	620.4	738.0
No. billfish raised	312	212	135	183
Fish raised per hour	0.370	0.262	0.218	0.248
Hrs. to raise 1 fish	2.7	3.8	4.6	4.0
Both areas combined				
No. hrs. trolled	1,563.9	909.0	1,363.3	851.5
No. billfish raised	389	228	288	190
Fish raised per hour	0.249	0.251	0.211	0.223
Hrs. to raise 1 fish	4.0	4.0	4.7	4.5

Table 14.—Relative abundance of billfishes by boat size for South Pass, northwest Florida, and the two areas combined, 1971.

Boat length (ft)[1]	10′-19′	20′-29′	30′-39′	40′-49′	50′-59′	60′-69′
South Pass						
Hours trolled	20.0	296.1	1,046.2	862.2	—	68.5
No. billfish raised	1	26	142	127	—	14
Fish raised per hour	0.050	0.088	0.136	0.147	—	0.204
Hrs. to raise 1 fish	20.0	11.4	7.3	6.8	—	4.9
Northwest Florida						
Hours trolled	42.1	695.3	1,092.8	4,142.5	1,163.8	60.0
No. billfish raised	3	130	182	1,049	278	4
Fish raised per hour	0.071	0.187	0.167	0.253	0.239	0.067
Hrs to raise 1 fish	14.1	5.3	6.0	4.0	4.2	14.9
Both areas						
Hours trolled	62.1	991.4	2,139.0	5,004.7	1,163.8	128.5
No. billfish raised	4	156	324	1,176	278	18
Fish raised per hour	0.064	0.157	0.152	0.235	0.239	0.140
Hrs. to raise 1 fish	15.6	6.4	6.6	4.3	4.2	7.1

[1] Meters = ft×0.3048.

We were able to determine the days during which various baits were used. Therefore, the only measure of effort we could use was the number of days each bait was used. Since the bait to which a billfish was raised was seldom recorded, and since a billfish will often raise to one bait and then go over to another, we decided that the bait the billfish took would be the best data to use for a study of bait preference. Therefore, for this analysis, our unit of measure for bait preference was the number of fish hooked per day with each bait. The results of our analysis are presented in Table 16.

Table 15.—Comparison of billfishes raised between boats 40′-49′ long with single screw and with twin screws, Destin, 1971.

Type of screw	Single	Twin
Hours trolled	686.5	2,965.3
Blue marlin		
No. raised	19	108
No. raised per hour	0.028	0.036
Hrs. to raise 1 fish	35.7	27.8
White marlin		
No. raised	36	267
No. raised per hour	0.052	0.090
Hrs. to raise 1 fish	19.2	11.1
Sailfish		
No. raised	96	436
No. raised per hour	0.140	0.147
Hrs. to raise 1 fish	7.1	6.8
All billfish[1]		
No. raised	151	821
No. raised per hour	0.220	0.277
Hrs. to raise 1 fish	4.5	3.6

[1] Includes unidentified billfish.

Various natural and artificial baits were fished but only the three most frequently used, mullet (*Mugil cephalus*), ballyhoo (*Hemiramphus* sp.), and bonito (*Euthynnus alleteratus*) strip, provided sufficient data for analysis. Under the category of "others" are included a wide variety which were used very infrequently and sporadically such as dusters, jigs, spoons, Kona heads, pork rind, ladyfish, strip dolphin, Spanish mackerel, croaker, cigar minnow, squid, needlefish, etc.

Because mullet is such a favored bait in the South Pass area, data for ballyhoo and bonito strip are sparse. Although the numbers of billfishes hooked per day using "other" baits are very similar to the rates using mullet as bait, conclusions regarding bait preference can not be made owing to the large assortment of baits lumped together in the "others" category.

In the northwest Florida area, the three types of baits were used frequently enough to permit conclusions. Blue marlin preferred mullet over ballyhoo and bonito strip as indicated by the respective hook rates (0.138, 0.090, and 0.080). The three types of baits were about equally effective for hooking white marlin (0.290, 0.278, 0.279). But sailfish very decidedly preferred bonito strip over mullet and ballyhoo (0.532 versus 0.226 and 0.228).

When the data for the two areas were combined, as shown at the bottom of Table 16, the results reinforced the conclusions reached for the northwest Florida area.

CONCLUSIONS

To summarize our study for 1971, the following results and conclusions were obtained:

1. A total of 701 billfishes was caught by sportfishermen in offshore waters of the northeastern Gulf of Mexico during 1971. Of the total, 99 were blue marlin, 284 were white marlin, and 318 were sailfish. To catch these, 11,107 hours of fishing were spent by the anglers.
2. During the same 11,107 hours, 492 blue marlin, 849 white marlin, and 860 sailfish, and 39 unidentified billfish were raised.
3. Off northwest Florida, white marlin were most abundant in July, sailfish were most abundant during the latter half of September, while blue marlin did not have an especially abundant period. Off South Pass, the variability of relative abundance from week to week was greater, making determinations of periods of abundance very uncertain.
4. Blue marlin were more abundant off South Pass than off northwest Florida. White marlin and sailfish were more abundant off northwest Florida.
5. Hours of greatest relative abundance for all billfishes were between 1000 and 1200 h and again between 1300 and 1500 h.
6. The bluer the water, the greater the relative abundance of billfishes.
7. Off South Pass, billfishes were most abundant along tide lines and rips, whereas off northwest Florida, they were most abundant in open water.
8. Effect of moon phase on billfishing was not significant.

Table 16.—Bait preference of billfishes for South Pass, northwest Florida, and the two areas combined, 1971.

Bait	Mullet	Ballyhoo	Bonito Strip	Others
South Pass				
No. of days bait used	330	25	3	47
Blue marlin				
No. hooked	74	1	0	11
No. hooked per day	0.224	0.040	—	0.234
White marlin				
No. hooked	44	5	1	6
No. hooked per day	0.133	0.200	0.333	0.128
Sailfish				
No. hooked	24	4	0	3
No. hooked per day	0.073	0.160	—	0.064
Northwest Florida				
No. of days bait used	465	421	376	231
Blue marlin				
No. hooked	64	38	30	26
No. hooked per day	0.138	0.090	0.080	0.113
White marlin				
No. hooked	135	117	105	46
No. hooked per day	0.290	0.278	0.279	0.199
Sailfish				
No. hooked	105	96	200	40
No. hooked per day	0.226	0.228	0.532	0.173
Both areas				
No. of days bait used	795	446	379	278
Blue marlin				
No. hooked	138	39	30	37
No. hooked per day	0.174	0.087	0.079	0.133
White marlin				
No. hooked	179	122	106	52
No. hooked per day	0.225	0.274	0.280	0.187
Sailfish				
No. hooked	129	100	200	43
No. hooked per day	0.162	0.224	0.528	0.155

9. Effect of lengths of boats on billfishing was not significant.
10. Boats 40 to 49 ft long raised more billfishe if they had twin screws than single screw.
11. Off northwest Florida, blue marlin pre ferred mullet as bait, sailfish preferre bonito strip, and white marlin showed n preference.

The results from 1971 represent only the begin ning of this study. In 1972, the area west of th mouth of the Mississippi River to the Mexican bo der will be included. Thus, future reports will cove the entire U.S. coast of the Gulf of Mexico. As da for the next few years are collected and analyze some of the conclusions reached for 1971 may altered, and where no conclusions were reached

971, definitive results may be obtained or trends nay be discerned.

ACKNOWLEDGMENTS

We are indebted to many people for helping us obtain the data on which this report is based. First, we very much appreciate the help given us by the officers of the cooperating organizations, namely, the New Orleans Big Game Fishing Club (H. Prager, Jr., President), Mobile Big Game Fishing Club (C.M.A. Rogers, III, Past President, and G. Cabanis, Jr., President), Pensacola Big Game Fishing Club (F. Neth, President), Destin Charter Boat Association (B. Bacon, President), and the Panama City Charter Boat Association (R. Stone, President). We are especially indebted to H. Howcott, who unselfishly spent much time and effort in helping us get our program underway and in advising us after the program was started. Some others who were extremely helpful in various ways were L. Ogren, G. Maddox, J. Yurt, R. Metcalfe, J. Ogle, J. Lockfaw, R. Schwartz, R. Brunson, T. Eastburn, K. Scales, III, F. Hubbard, C. Hughes, J. Dunlap, K. Reed, L. Freeman, F. Jones, and R. Martin. Finally, we owe much to all boat captains and anglers who provided us with data.

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Angler Catch Rates of Billfishes in the Pacific Ocean

JAMES L. SQUIRE, JR.[1]

ABSTRACT

In 1969, 1970, and 1971 marine game fish anglers participating in the Pacific phase of the National Marine Fisheries Service cooperative marine game fish tagging program were asked to complete a postcard form which requested information of the number of days of billfishing the angler engaged in and the catches made. From the 17,876 angler days reported, the catch consisted of 10,234 billfishes. The average for the 3-yr period was 0.57 billfish per angler-day or 1.75 days of fishing per billfish. Analysis of data for the geographical areas in the eastern Pacific and Australia (Queensland) where billfishing is conducted resulted in a wide range of catch per effort for all billfish species combined. Off southern California, U.S.A., the catch was 0.10 fish per angler-day, equaling 10.3 days of fishing per fish. Off Baja California, Mexico, records show 0.82 fish per angler-day equaling 1.22 days fishing per fish, and fishing off Mazatlán yielded 1.21 fish per angler-day and 0.82 days fishing per fish. Off Acapulco, Mexico, the results were 0.95 fish per angler-day and 1.05 days per fish. Fishing off Australia the records show 0.55 fish per angler-day equaling 1.83 days per fish.

The measurement of catch rates is of value in evaluating fishing success relative to seasonal changes, specific types of fishing gear or changes in gear, and effects of environmental change. However, its greatest use has been in the determination of the effect of fishing on the stock or stocks of fish being utilized by sport and commercial fisheries.

The only comprehensive sources of catch and effort data for billfishes in the Pacific Ocean are the reports of the commercial longline fishery for tunas and billfishes published by the Research Division of the Japanese Fisheries Agency. These data have been used by researchers in the eastern Pacific in determination of commercial catch rates for billfishes (Suda and Schaefer, 1965; Kume and Schaefer, 1966; Kume and Joseph, 1969).

The billfish sport fishery in the northeastern Pacific off Mexico and the United States is reported to capture at least 10,000 fish each year (Talbot[2]); however no accurate totals for sport-caught billfishes are available. The number of billfishes taken by the sport fishery is a fraction of that landed by the commercial fishery. However, the economic value of the sport fishery resulting from the expenditure for goods and services by the thousands of billfish anglers in the pursuit of the sport is assumed to be substantial.

The problems in obtaining a measure of catch an effort in marine sport fisheries are many. In contras to a commercial fishery, where commercial landing and sometimes fishing records are kept and th number of operating units is known, the sport fisher consists of many small and mobile units which ma or may not land their billfishes at locations where record of the landing might be made. A report o the problem of obtaining sport fishery statistics wa made by the Institute of Statistics, University North Carolina (D. W. Hayne, 1964[3]) and many the observations in that report are applicable to th design of a statistically accurate billfish angler su vey.

As part of the cooperative marine game fish ta ging program, conducted first at the Tiburon Mari Laboratory, Tiburon, California, and later at th Southwest Fisheries Center, La Jolla, California, annual report describing the progress in billfish ta ging was mailed to individuals that had participated in the program. This mailing list consisted of names of billfish anglers, most of whom fished in the eastern Pacific or off the east coast of Australia.

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[1] Southwest Fisheries Center, National Marine Fisheries Service, NOAA, La Jolla, CA 90237.

[2] Talbot, Gerald B., U.S. Bureau of Sport Fisheries and Wildlife, Clemson University, P.O. Box 429, Clemson, S.C. Personal communication.

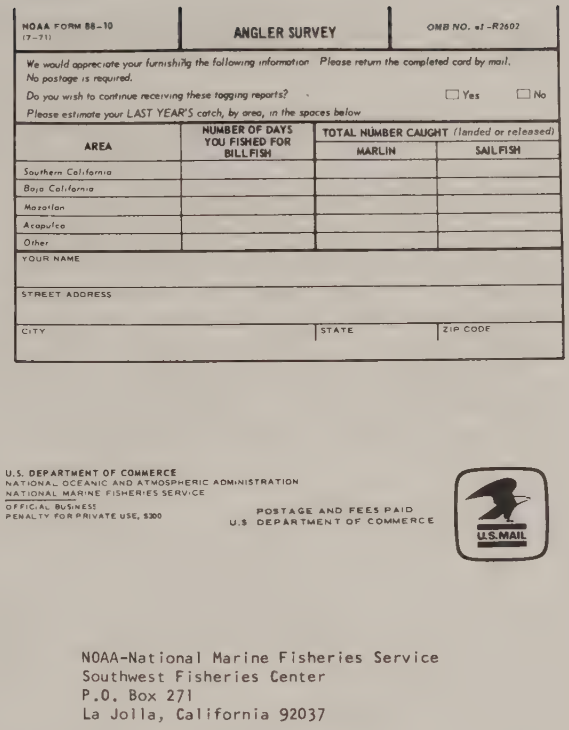
[3] Hayne, D. W., The measurement of catch and effort in mar sportfishing. Report to the U.S. Bureau of Sport Fisheries Wildlife, September 15, 1964. Institute of Statistics, Raleigh S tion, North Carolina State, University of North Carolina, mer 23 p.

In the annual reports for 1969, 1970, and 1971, a postcard was enclosed requesting information on the amount of fishing effort and catch. The billfish angler was asked to recall the number of days of billfishing and the number of billfish caught by species. The anglers were requested to give an "honest" answer and told that information on zero catches was important. The technique of postcard survey has been the subject of considerable controversy. The California Department of Fish and Game has used this technique and a number of researchers have published on the results of this type of survey (Calhoun, 1950, 1951; Clark, 1953; Pelgen, 1955; Abramson, 1963; Jensen, 1964).

Hayne reported that it is difficult for a fisherman to remember precisely his catch of the previous year. However, with regard to billfishes, the frequency at which the average billfish angler participates in the sport is limited and the annual catch of billfish per angler is small. Billfish are "trophy fish" and the author believes that the average billfish angler can recall within close limits the number of fish caught during the previous year and the number of days he participated in the fishery.

METHODS

A sample of the questionnaire used is shown in Figure 1. The form was also used to update the mailing list for the Cooperative Marine Game Fish Tagging Program annual report. The postcard form was sent to the billfish anglers in February of 1970, 1971, and 1972, and a prompt return of the card was requested. The number of survey cards sent each



NOAA FORM 88-10 (7-71)	ANGLER SURVEY	OMB NO. 41-R2602

We would appreciate your furnishing the following information Please return the completed card by mail.
No postage is required.
Do you wish to continue receiving these tagging reports? ☐ Yes ☐ No
Please estimate your LAST YEAR'S catch, by area, in the spaces below

AREA	NUMBER OF DAYS YOU FISHED FOR BILLFISH	TOTAL NUMBER CAUGHT (landed or released)	
		MARLIN	SAILFISH
Southern California			
Baja California			
Mazatlan			
Acapulco			
Other			

YOUR NAME
STREET ADDRESS
CITY | STATE | ZIP CODE

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL MARINE FISHERIES SERVICE
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NOAA-National Marine Fisheries Service
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La Jolla, California 92037

Figure 1.—Angler survey card.

Table 1.—Combined catch and effort data for surveys conducted in 1969, 1970, and 1971.

Area	Angler days	Species/catch (numbers)			Catch rates	
		Striped marlin	Sailfish	Black marlin	Fish/angler day	Days/fish
USA						
Southern California	6,458	593	51	0	0.10	10.03
Mexico						
Baja California	8,710	6,168	964	0	0.82	1.22
Mazatlán	1,316	697	900	0	1.21	0.82
Acapulco	249	16	221	0	0.95	1.05
Australia (Queensland)						
Cairns	1,143	0	172	452	0.55	1.83
Total	17,876	=10,234 (all species)			Aver. 0.57	Aver. 1.75

year with the annual tagging report varied from 1,900 to 2,600.

RESULTS

Approximately 50% of the survey cards were returned within a 3-mo period and the number of angler days in each of the major fishing areas, the number of billfishes caught, and calculations of numbers of fish per angler day and numbers of days of fishing per fish are given in Table 1.

The combined totals for the fishing areas off southern California, U.S.A., about the tip of Baja California, Mazatlán, and Acapulco, Mexico, and Cairns, Queensland, Australia, were 17,876 angler days, catching 10,234 billfishes for an average of 0.57 fish per day and 1.75 days of fishing for each billfish.

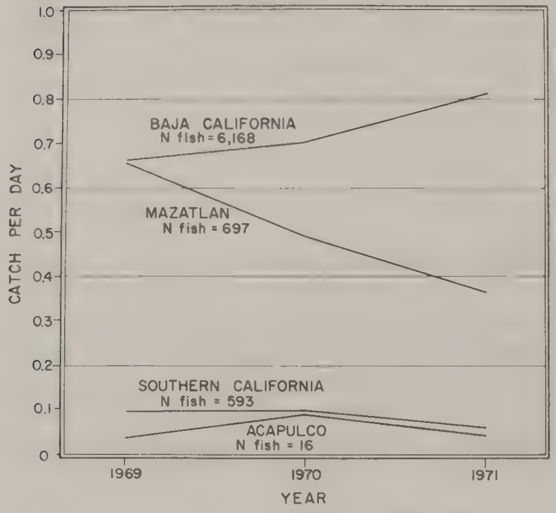

Figure 2.—Sport fishing catch per day for striped marlin in the eastern Pacific.

A breakdown of the totals given in Table 1 for each year is presented in Table 2.

For these selected fishing areas the annual statistics from the survey on total catch and effort are as follows: 1969, 6,286 angler days, 3,404 billfishes caught equaling 0.54 fish per day and 1.90 days of fishing per fish; 1970, 6,286 angler days, 3,588 billfishes caught equaling 0.58 fish per day and 1.75 days of fishing per fish; 1971, 5,304 angler days, 3,242 billfishes caught equaling 0.61 fish per day and 1.64 days of fishing per fish.

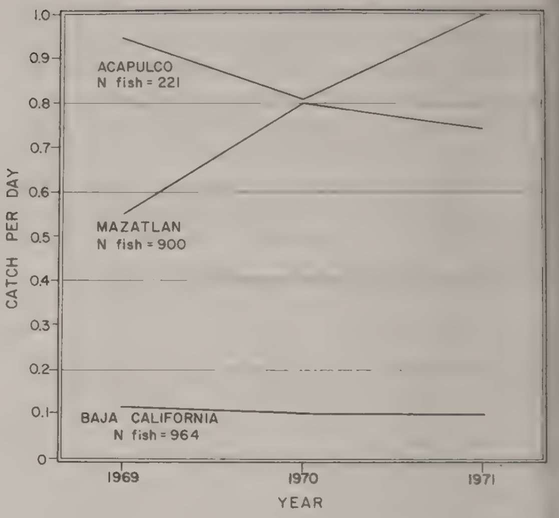

Figure 3.—Sport fishing catch per day for sailfish in the eastern Pacific.

A graphic presentation of the catch per effort data is given for striped marlin *Tetrapturus audax* in Figure 2; for sailfish *Istiophorus platypterus* in Figure 3; and for black marlin *Makaira indica* in Figure 4. Catch per effort data for combined

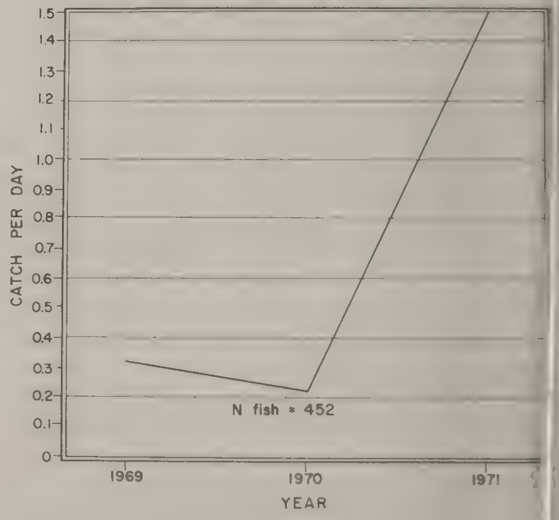

Figure 4.—Sport fishing catch per day for black marlin Queensland, Australia.

Table 2.—Catch and effort data for the years 1969, 1970, and 1971 by species and by area.

Area	Angler days	Striped marlin			Sailfish			Black marlin			Total		
		Catch	Catch/ angler day	Days/ fish	Catch	Catch/ angler day	Days/ fish	Catch	Catch/ angler day	Days/ fish	Catch	Catch/ angler day	Days/ fish
1969													
Southern California	2,297	220	0.10	10.44	—	—	—	—	—	—	220	0.10	10.44
Baja California	2,519	1,657	0.66	1.52	314	0.12	8.02	—	—	—	1,971	0.78	1.27
Mazatlán	583	382	0.65	1.52	322	0.55	1.81	—	—	—	704	1.21	0.83
Acapulco	112	5	0.04	10.70	106	0.94	1.05	—	—	—	111	0.94	1.05
Cairns (Australia)	775	—	—	—	162	0.21	4.66	236	0.31	3.20	398	0.53	1.93
1970													
Southern California	2,068	221	0.01	9.30	11	<0.00	88.0	—	—	—	232	0.11	8.90
Baja California	3,398	2,258	0.70	1.50	357	0.10	9.50	—	—	—	2,615	0.77	1.30
Mazatlán	461	214	0.50	2.10	374	0.80	1.20	—	—	—	588	1.27	0.80
Acapulco	97	9	0.09	10.70	75	0.80	1.20	—	—	—	84	0.86	1.15
Cairns (Australia)	262	—	—	—	10	0.03	26.2	59	0.22	4.40	69	0.26	3.70
1971													
Southern California	2,093	152	0.07	13.70	40	0.02	52.30	—	—	—	192	0.09	10.90
Baja California	2,793	2,253	0.82	1.24	293	0.10	9.50	—	—	—	2,546	0.91	1.10
Mazatlán	272	101	0.37	2.69	204	0.75	1.33	—	—	—	305	1.12	0.89
Acapulco	40	2	0.05	20.00	40	1.00	1.00	—	—	—	42	1.05	0.95
Cairns (Australia)	106	—	—	—	—	—	—	157	1.48	0.69	157	1.48	0.69

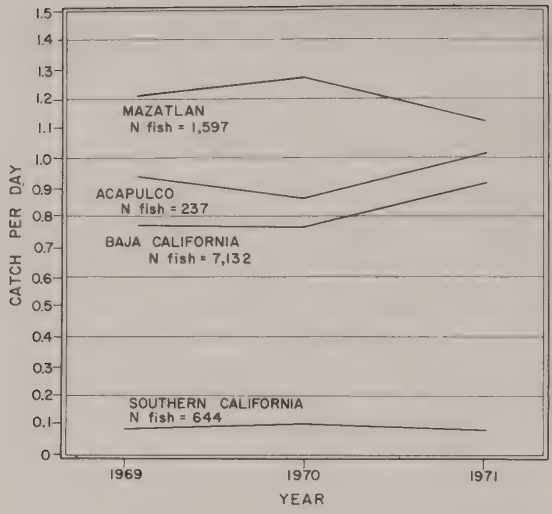

Figure 5.—Combined species (striped marlin and sailfish) catch per day in the eastern Pacific.

species of billfish at locations in the eastern Pacific are shown in Figure 5.

SUMMARY AND DISCUSSION

Striped marlin catch and effort data for fishing off southern California show a catch rate of 0.10 fish per day or less, and the catch rate off Acapulco is lower than southern California. The Baja California, Mexico, catch rate is highest, ranging between 0.66 and 0.82 fish per day with a slight increase shown in the catch rate in 1971 as compared to 1969. For the fishing area off Mazatlán the catch rate has declined from 0.65 to 0.37 during the survey years.

During the 3-yr period catch rates for sailfish ranged about the 0.9 to 1.0 fish-per-day level off Acapulco and the 0.55 to 0.80 fish-per-day level off Mazatlán. The catch rate is much lower off Baja California than off Mazatlán and Acapulco, remaining steady at a rate of about 0.1 fish per day. Black marlin catch rates off Cairns, Australia varied considerably from a low of 0.22 to a high in 1971 of 1.48 fish per day.

In 1968 and 1969 the Tiburon Marine Laboratory conducted field sampling for billfishes about the tip of Baja California and at Mazatlán, Mexico. Catch and effort data were collected from available sources such as the sportfishing fleet operators and Mexico's Department of Tourism. Catch and effort data for Mazatlán and Las Palmas Bay (at the tip of Baja California) are shown in Figure 6. Statistical data from the field sampling program show a catch rate for sailfish at Mazatlán of 0.74 fish per day and the postcard angler survey shows about 0.70 fish per day. For striped marlin caught about the tip of Baja California, Mexico, the Las Palmas Bay data shows a catch rate of 0.60 fish per day, the angler postcard survey shows about 0.75 fish per day.

Comparative catch-per-unit-effort data are not available for southern California waters, but experienced anglers state the figure of 0.10 billfish per day appears reasonable.

Marine game fishing for billfishes is an important economic factor in many areas of the world. The monetary expenditure of marine anglers per billfish caught is recognized as substantial. The point

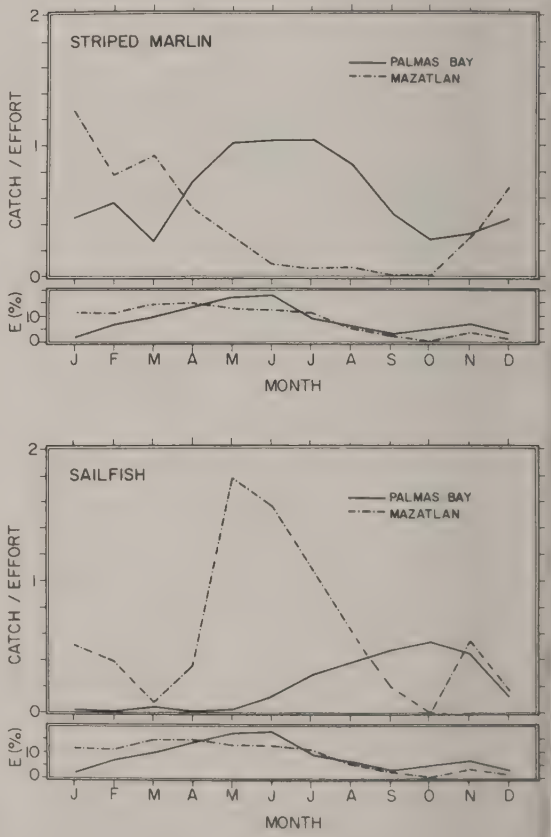

Figure 6.—Striped marlin (upper panel) and sailfish (lower panel) catch and effort rates off Las Palmas Bay (tip of Baja California) and Mazatlán, Mexico, 1968-1969

(catch per effort level) at which the majority of anglers will cease to fish is dependent upon location and accessibility of the fishing grounds. An example of this is billfishing off southern California, which has by the angler survey records a low catch rate of 0.10 fish per day, or 10.02 days per billfish. The accessibility of the fishing grounds to the large southern California fleet of sportfishing boats makes for a large effort in spite of a low catch. If this same catch rate were common about the tip of Baja California, Mexico, the number of U.S. anglers traveling to this distant area to fish for billfishes might be only a fraction of the present number.

The angler survey sampled to a greater degree those individuals who participated in the tagging program, and had fished off southern California, the west coast of Mexico, west coast of Central America, or Australia. The postcard survey method for obtaining billfish catch and effort data has the potential of sampling more billfish anglers than any other method. Selection of a mailing list based on active billfish anglers belonging to the major billfish clubs throughout the United States and in other countries could provide a sampling frame for a reliable worldwide statistical determination of sportfishing catch and effort activity. The postcard method could provide a source of continuing information on the status of billfish angling relative to the resource base on which it depends for the least monetary expenditure, when compared with other sampling methods.

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The Canadian Swordfish Fishery[1]

S. N. TIBBO and A. SREEDHARAN[2]

ABSTRACT

During the early 1960's the traditional harpoon fishery for swordfish off the east coast of Canada was replaced by a longline fishery. Fishing areas and seasons expanded, landings increased and size composition of the catch decreased. Catch and effort data for the period 1958 to 1970 covering both fishing methods were analyzed and the results are presented.

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[1] Abstract only; this paper was presented orally, but only title and abstract were submitted for publication.

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Landings of Billfishes in the Hawaiian Longline Fishery

HOWARD O. YOSHIDA[1]

ABSTRACT

The landings of the Hawaiian longline fishery are dominated by the tunas. During 1964 to 1967, the tunas, by weight, made up an average of 66% of the catch, whereas the marlins and swordfish, *Xiphias gladius*, comprised about 34%. The catch of billfishes is composed of the striped marlin, *Tetrapturus audax*, blue marlin, *Makaira nigricans*, black marlin, *M. indica*, sailfish, *Istiophorus platypterus*, shortbill spearfish, *T. angustirostris*, and swordfish.

The annual landings of blue marlin ranged between 47 and 366 metric tons during 1952 to 1970. The annual landings of striped marlin fluctuated between 93 and 228 metric tons during the same period. The blue marlin dominated the catch from 1952 to 1961. Subsequent to 1963, the billfish catches have been dominated by the striped marlin.

The monthly landings and the monthly catch rates of blue marlin and striped marlin showed similar trends. The monthly landings of striped marlin, however, showed greater fluctuations than the monthly catch per unit of effort. This was attributed in part to a change in the size composition of striped marlin in the third quarter.

The Hawaiian longline fishery has been described in the past primarily from the viewpoint of a fishery for deep-swimming tunas, usually yellowfin tuna, *Thunnus albacares*, and bigeye tuna, *T. obesus*. June (1950), Otsu (1954), Shomura (1959), and Hida (1966) all have made studies on this fishery as it related to the tunas. One of the exceptions is a paper by Strasburg (1970) on the billfishes of the central Pacific Ocean, in which he briefly discussed the billfishes landed in Hawaii. This report considers the Hawaiian longline fishery as it relates to the billfishes, particularly the blue marlin, *Makaira nigricans*, and the striped marlin, *Tetrapturus audax*, primarily during the period from 1963 to 1970.

The data used for this report came primarily from two sources. The billfish landing data through 1968 were obtained from the Fishery Statistics of the United States. The landing data for 1969 and 1970 and fishing trip data are from the files of NMFS (National Marine Fisheries Service), Honolulu, Hawaii. Billfish weight and sex data from 1964 to the middle of 1970 were collected at the Honolulu auction markets by samplers from our Laboratory.

DESCRIPTION OF THE FISHERY

The Hawaiian longline fishery is the only American fishery employing the longline method of fishing (Shomura, 1959). The history and description of the fishery are given by June (1950) and Otsu (1954).

Typical Hawaiian longline boats evolved from the Japanese sampan-type, live-bait boat (June, 1950). They are characterized by a narrow bow, angular lines and a low freeboard aft. The overall length of these vessels ranges from 8.53 to 18.90 m (28 to 62 ft). All except one of the vessels in the Hawaiian fishery have wooden hulls. The length of a fishing trip averages 8 or 9 days for a Honolulu-based vessel and the majority of the trips are made within sight of the main Hawaiian Islands (Shomura, 1959).

The number of longline boats in the Hawaiian fleet has steadily declined over the years. In 1952 there were 42 boats in the Hawaiian fishery. In 1964 the number was down to 31 and in 1970 to 20. Although the number of boats in the fishery has been declining, one new boat was recently added to the longline fleet. This vessel has a steel hull and a refrigerated fish hold, and has an extended cruising range. The vessel began operations in July 1969 and has fished as far as 1,482 km (800 miles) from the Hawaiian Islands (Kanayama, 1970).

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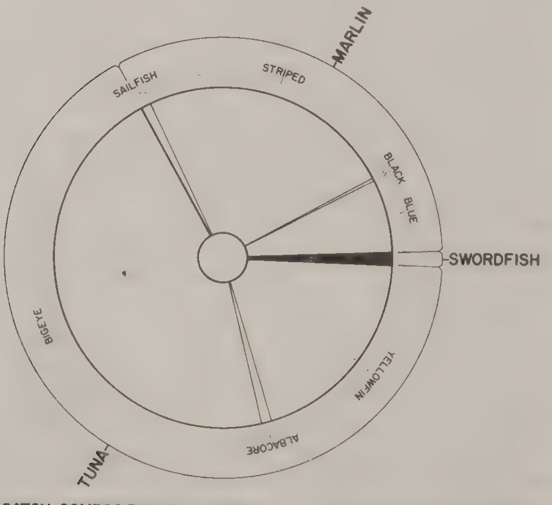
[1] NOAA, National Marine Fisheries Service, Southwest Fisheries Center, Honolulu Laboratory, Honolulu, Hawaii 96812.

Similar to the Japanese longline fisheries, the catches in the Hawaiian longline fishery are made up mostly of large tunas. During the period from 1964 to 1967, considering only the tunas and the billfishes, the tunas, by weight, made up about 66% of the catch, the marlins about 32%, and the swordfish, *Xiphias gladius,* about 1% (Fig. 1). Among the tunas, bigeye tuna dominated the catch followed by yellowfin tuna and albacore, *Thunnus alalunga.* Among the billfishes, striped marlin dominated the catch, followed by blue marlin and swordfish. Small numbers of sailfish, *Istiophorus platypterus,* and shortbill spearfish, *Tetrapturus angustirostris,* are also taken. In 1970, the tunas and billfishes landed by the longline fishery were valued to the fishermen at $1,311,471. The billfishes contributed $291,837 (22%) to this amount.

Other species taken on the longline, in their order of importance, are dolphin or mahimahi, *Coryphaena hippurus:* wahoo, *Acanthocybium solandri;* and a few skipjack tuna, *Katsuwonus pelamis.*

LANDINGS OF STRIPED MARLIN AND BLUE MARLIN

The annual landings of blue marlin ranged between 47 and 366 metric tons during the period from 1952 to 1970 (Fig. 2). The landings declined steadily from a high of 366 metric tons in 1954 to a low point of 48 metric tons in 1968. The landings recovered a little in 1969 and 1970.



CATCH COMPOSITION (BY WEIGHT) OF HAWAIIAN LONGLINE FISHERY

Figure 1.—Composition of the tuna and billfish landings in the Hawaiian longline fishery.

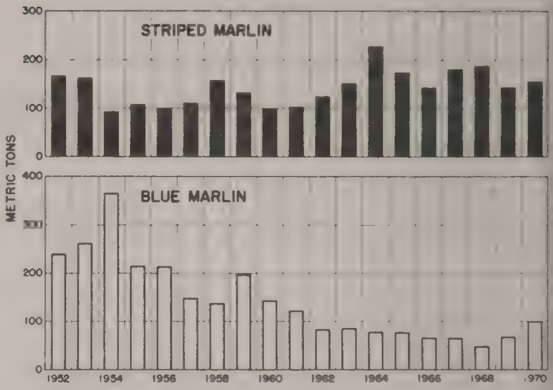


Figure 2.—Annual landings of blue marlin and striped marlin from 1952 to 1970 in Hawaii.

The annual landings of striped marlin fluctuated between 93 and 228 metric tons during this same period (Fig. 2). No clear trends are evident in the landings although it appears that the landings between 1963 and 1970 were slightly higher than the landings prior to 1963. Of interest is the change in dominance from blue marlin to striped marlin in the landings beginning in 1962. This change was caused primarily by the declining blue marlin catches.

Strasburg (1970) presented data on the monthly landings of blue marlin and striped marlin in the Hawaiian fishery from 1950 to 1963. For the perio 1950 to 1960, Strasburg noted a complementary na ture in the landings of the two species in that stripe marlin were caught in large numbers when the blu marlin catches were lowest and vice versa. H noted, however, that the landing peaks of the tw species tended to coincide in 1961 and 1962. Monthl landings from 1963 to 1970, however, again showed displacement in peak landings for striped marlin an blue marlin (Fig. 3). Blue marlin catches were high est in summer and lowest in winter, whereas stripe marlin were more abundant in the winter than in th summer. The striped marlin landings were al characterized by having more than one peak in year, and by wide fluctuations from month to mont The biggest dip in the landings each year usua occurred in the third quarter.

Of interest is a similar complementary nature the catches of yellowfin tuna and bigeye tuna in t Hawaiian longline fishery. The peak catches of y lowfin tuna are made during the summer while go

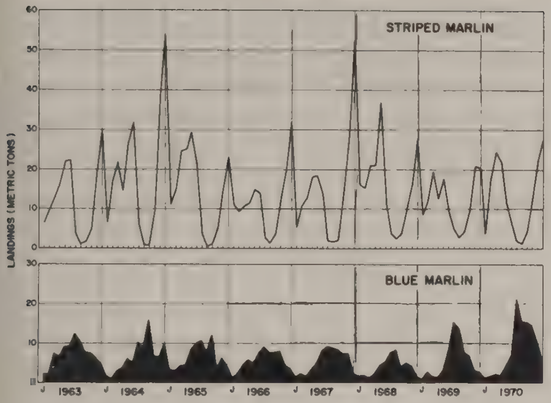


Figure 3.—Monthly landings of blue marlin and striped marlin from 1963 to 1970 in Hawaii.

catches of bigeye tuna are made during the winter and spring (June, 1950; Otsu, 1954; Shomura, 1959). This suggests that striped marlin and bigeye tuna may be responding to a different set of environmental factors from the blue marlin and yellowfin tuna. Strasburg (1970) has suggested a relation to the food supply to explain the complementary abundance of striped marlin and blue marlin around Hawaii. He noted that blue marlin fed largely on skipjack tuna, which were more abundant in the summer. This may account for the larger numbers of blue marlin during the summer.

Further evidence that the blue marlin are indeed responding to the presence of their prey can be seen in the relation between the landings of skipjack tuna and blue marlin in Hawaii (Fig. 4). Generally speaking, good catches of blue marlin corresponded to good catches of skipjack tuna. The situation in 1965, however, did not conform to the general trend. The reason for this is not known.

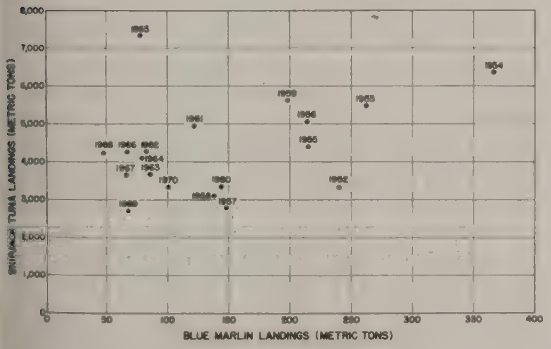


Figure 4.—Relation between landings of skipjack tuna and blue marlin in Hawaii.

CATCH PER UNIT OF EFFORT

The CPUE (catch per unit of effort) for striped marlin and blue marlin was determined to see if CPUE had any effect on the monthly landings. As Shomura (1959) indicated, measures of effort such as number of hooks or baskets of gear fished, are not readily available for the Hawaiian longline fishery. Thus for his analysis of the abundance of tunas around Hawaii, he used the number of trips as a measure of effort. Following Shomura, the number of trips was used to calculate CPUE, here given as number of fish caught per trip on a monthly basis (Fig. 5).

The catch rates for striped marlin and blue marlin showed the same trends as the monthly landings. Similar to the monthly landings blue marlin catch rates usually peaked from July to September. During the period from 1961 to 1969, however, the annual summer peak in the catch rates has shown a small but steady decline.

Similarly, the monthly catch rates of striped marlin showed the same trends, although the fluctuations were not as pronounced as the monthly landings. As did the monthly landings, the monthly catch rates for striped marlin showed two peaks annually, usually one in the spring and the other in the fall. In contrast to the blue marlin, the annual peaks in the monthly catch rates for striped marlin from 1961 to 1969 have increased slightly.

SIZE OF FISH

The quarterly weight-frequency distribution of striped marlin by sex is shown in Figure 6. The size

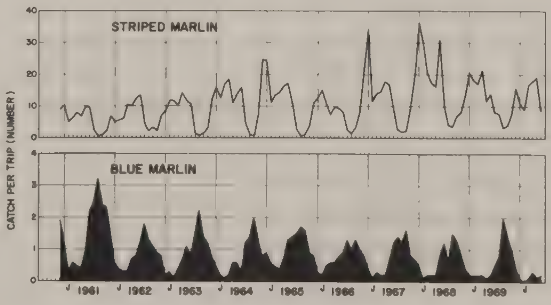


Figure 5.—Monthly catch per trip of blue marlin and striped marlin.

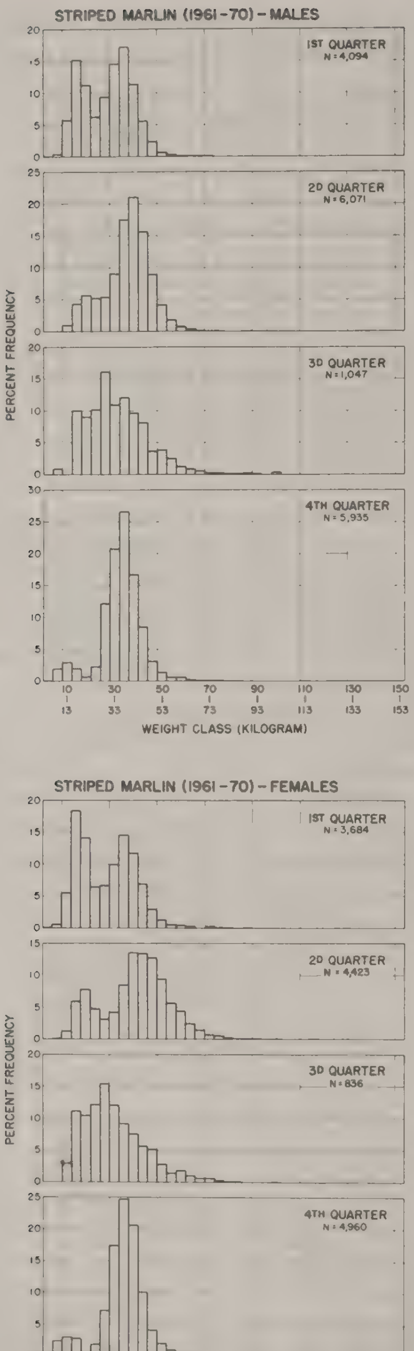


Figure 6.—Weight-frequency distribution of striped marlin.

of male and female striped marlin are about identical and the size-frequency distribution of the males and females show almost no difference. They ranged from 3 to 147 kg (7 to 324 lb). It is interesting that during the first, second, and fourth quarters, the size-frequency distribution shows a bimodal distribution while in the third quarter the size distribution only shows one mode. In the first quarter the modes are located between 14 and 18 kg (31 and 40 lb) and 34 and 38 kg (75 and 84 lb), in the second quarter between 18 and 22 kg (31 and 48 lb) and 38 and 46 kg (84 and 101 lb), and in the fourth quarter between 10 and 14 kg (22 and 31 lb) and 34 and 38 kg (75 and 84 lb). In the third quarter the single mode is located between 26 and 30 kg (57 and 66 lb).

It was noted earlier that the monthly landings showed greater fluctuations than the monthly catch rates and that the biggest dip in the landings was found consistently during the third quarter. This was apparently caused by a combination of low catch rates and the presence of only intermediate size fish in the landings in the third quarter. In the third quarter striped marlin represented by the larger of the two modes found in the other three quarters are evidently not present in large numbers in Hawaiian waters.

Of interest is the observation that larvae of striped marlin are not found in Hawaiian waters (Matsumoto and Kazama, 1974). Matsumoto and Kazama have suggested several reasons for the absence of striped marlin larvae, including the possibility that adult striped marlin leave Hawaiian waters to spawn elsewhere. They cite as evidence the absence of the larger size group of striped marlin in the Hawaiian Islands area starting in about July. As noted above my data show that the larger striped marlin are no present in the commercial landings in large number in the third quarter.

In contrast to the striped marlin, the blue marli show striking differences in size between the sexe and also in their size distribution (Fig. 7). Th females grow to be much larger than the males; the ranged from 7 to 444 kg (15 to 979 lb). In the first an fourth quarters no clearly defined modes are prese in the female weight-frequency distribution. In th second quarter a single mode is evident between 14 and 144 kg (309 and 317 lb). The third quarter di tribution shows a mode between 120 and 184 kg (26 and 406 lb).

The size distributions of the males, on the oth hand, show a pronounced mode between 44 and 8 kg (97 and 176 lb) in all quarters of the year. The ranged from 12 to 140 kg (26 to 309 lb).

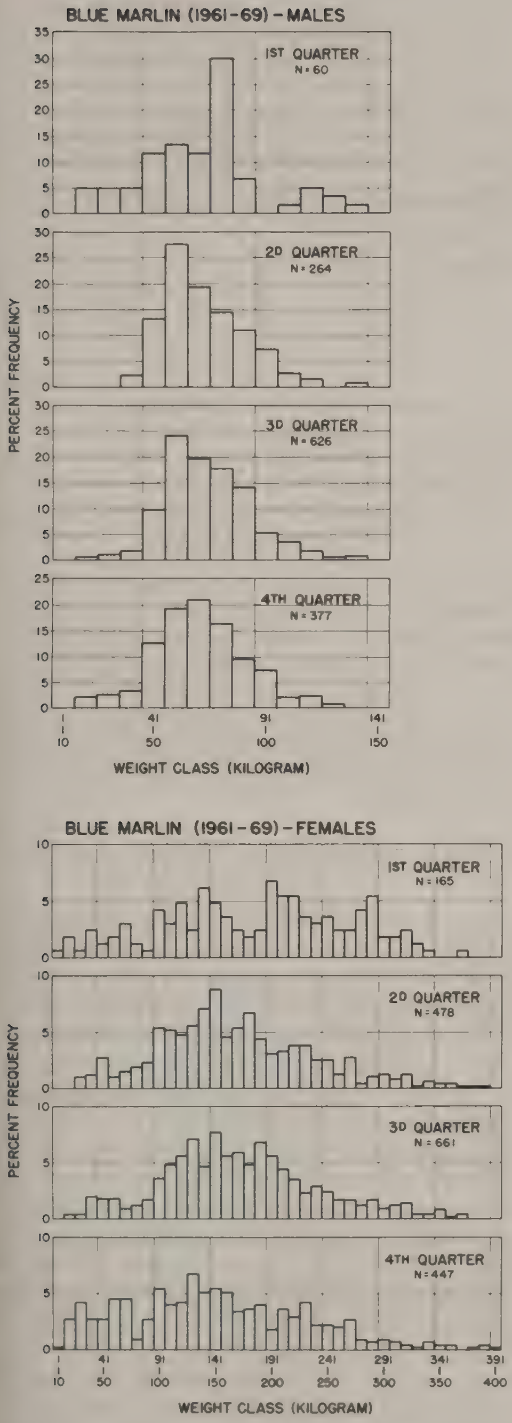


Figure 7.—Weight-frequency distribution of blue marlin.

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Fishery-Oceanographic Studies of Striped Marlin, *Tetrapturus audax*, in Waters off Baja California. I. Fishing Conditions in Relation to the Thermocline

EIJI HANAMOTO[1]

ABSTRACT

In this report, the author analyzed fishing conditions for striped marlin in waters off Baja California in relation to the thermocline. The results were as follows:

1. In subarea SW, bounded by lat. 15°-25°N and long. 115°-110°W, catch rates begin increasing from about May and reach a peak between July and October. In subarea SE, bounded by lat. 15°-25°N and long. 110°-105°W, there appears to be a tendency for catch rates to be highest from July through October. In subarea M, bounded by lat. 10°N to along the coast of Mexico and long. 105°-95°W, catch rates are highest between May and July.

2. From December through March there is good fishing in relatively narrow areas around the tip of Baja California. In April, a good fishing ground appears off Manzanillo and in May this ground begins to expand seaward. From June, the area of good fishing off the coast from Acapulco to Mazatlán begins to expand seaward and the greatest expansion of grounds occurs off Baja California in September. In October, the ground becomes narrow and is located farther east.

3. The pattern of expansion and contraction of the shallow thermocline area coincides fairly closely with the pattern of expansion and contraction of good fishing grounds. One of the factors related to this phenomenon is that the formation of good fishing grounds off Baja California is considered to be related to the shallow thermocline areas where there is a more abundant food supply.

The waters off Baja California have been known to be a good subsurface fishing ground for striped marlin, *Tetrapturus audax*, ever since the Japanese tuna longline fishery began fishing the area in 1963. This same area is also a good surface fishing ground for yellowfin tuna, *Thunnus albacares*, and skipjack tuna, *Katsuwonus pelamis*.

Although several studies have been carried out on striped marlin in the eastern tropical Pacific (Howard and Ueyanagi, 1965; Kume and Joseph, 1969; Shiohama, 1969), there has been relatively little work done on the relationships between the fish and the environment. The main purpose of this study is to describe the formation mechanism of the striped marlin fishing ground in this area through the examination of the monthly distribution of striped marlin, seasonal variations in catch rates and size compositions, and the relationship between fishing conditions and the thermocline.

MATERIALS AND METHODS

In order to examine the seasonal variations in catch rates of striped marlin, the data were summarized by subareas as shown in Figure 1. These subareas, SW, SE, and M, were designated on the basis of similarities in trends in the monthly distributions of mean relative abundance of striped marlin.

The source of data used in examining seasonal variations in relative abundance (Figs. 2, 3, 4) was the "Annual Report of Effort and Catch Statistics by Area on Japanese Tuna Longline Fishery" for 1963-70 (Japan. Fisheries Agency, Research Division, 1966-72). Numbers of hooks fished and fish caught were summarized by month and by 5° squares, and the monthly catch rate in each subarea was calculated as follows:

Catch rate in a subarea = $(\Sigma C_i/\Sigma F_i) \times 100$
where C_i = number of fish caught in the ith 5° square
F_i = number of hooks fished in the ith 5° square.

Monthly distributions of mean relative abundanc (Fig. 5) were based on averages for the years 1966-7

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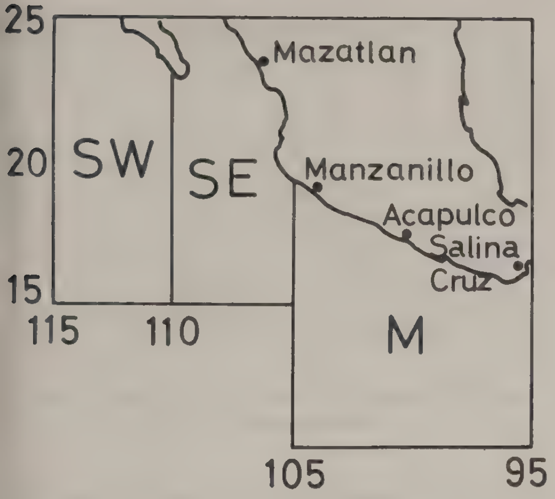

Figure 1.—Subareas selected for examination of striped marlin catch rates.

from data obtained through the courtesy of the Far Seas Fisheries Research Laboratory. Size composition data from the same source were summarized by quarters of the year for 1965 and 1967-70 for two subareas (as shown in Figs. 6 and 7). Monthly thermocline topography (Fig. 8) was obtained directly from the atlas of Robinson and Bauer (1971).

SEASONAL VARIATIONS IN CATCH RATES

Monthly variations in the catch rates for striped marlin in waters off Baja California (subareas SW and SE) and off southern Mexico (subarea M) are shown for the years 1963-70 in Figures 2, 3, and 4.

In subarea SW (Fig. 2), the catch rates are lowest from January through April, begin increasing from about May, reach a peak between July and October, and then decrease after November. It is noted that there are relatively small between-year differences in catch rates in this subarea.

In subarea SE (east of SW) the catch rates show a marked between-year variation (Fig. 3). The wide fluctuations appear to be especially noticeable in March and April, e.g. the lowest monthly catch rate in 1968 occurred in April, which was also the month showing the highest catch rate for 1970. The between-year variability was least during the July-September period.

In subarea M, off southern Mexico, catch rates are generally low between January and March. They begin increasing in April and are highest between May and July (Fig. 4). After August the catch rates tend to become lower, although the year-to-year fluctuation is considerable.

SIZE COMPOSITION

The average weight-frequency distribution, by quarters of the year, was compiled for the two subareas shown in Figure 6. In the waters off Baja California (subarea S′), the modal weight of the larger size group is observed at 31 to 35 kg during the first quarter (I-Q), at 35 to 39 kg during the second quarter (II-Q), and at 39 to 47 kg during the third quarter (III-Q) (Fig. 7). The average modal weights tend to increase from the first to the third quarters. There is only one size group during the third and fourth quarters. The modal weight during the fourth quarter (IV-Q) is 27 to 31 kg and is smaller than that of the third quarter. There are two size groups during the first and second quarters, the modal weights being 11 to 15 kg and 15 to 19 kg, respectively.

Data for subarea M′ are available only for the second quarter. During the second quarter two size groups are present—one with a mode at 27 to 31 kg and the other at 43 to 47 kg. The modal group of the smaller-size fish is the more dominant of the two groups.

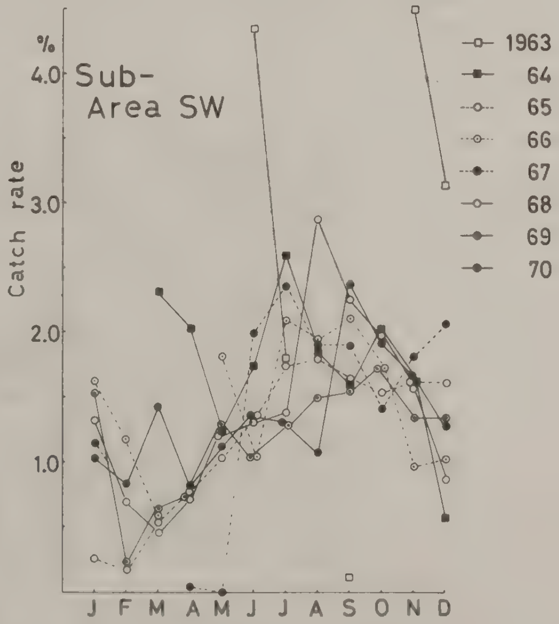

Figure 2.—Monthly variations in catch rates of striped marlin in subarea SW, 1963-70.

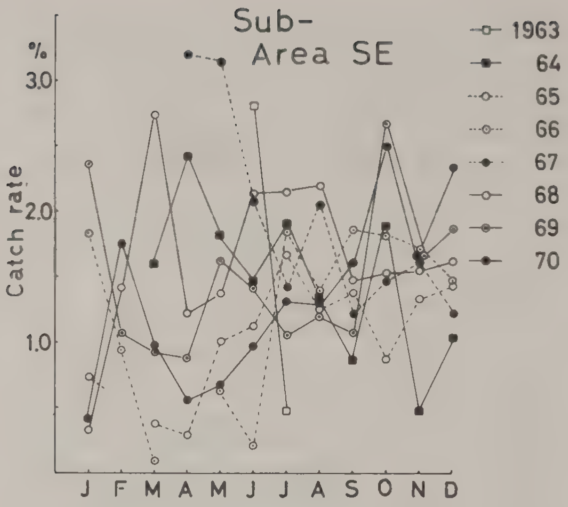

Figure 3.—Monthly variations in catch rates of striped marlin in subarea SE, 1963-70.

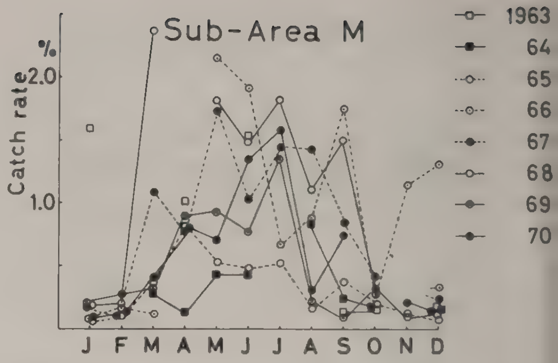

Figure 4.—Monthly variations in catch rates of striped marlin in subarea M, 1963-70.

SEASONAL SHIFTS IN FISHING GROUNDS

Monthly distributions of mean relative abundance of striped marlin in waters off Baja California and southern Mexico for the period 1966-70 are shown in Figure 5. Areas of high (more than 1.5%), medium (between 1.4 and 0.5%) and low (less than 0.4%) relative abundance are contoured. From December through March good fishing grounds appear in relatively narrow areas around the tip of Baja California and near the mouth of the Gulf of California. In April, the ground near the Gulf entrance disappears, and in its place good fishing appears off Manzanillo. In May, good fishing begins to expand seaward as far as long. 110°W. At the same time another good fishing ground appears off Salina Cruz. Good fishing off Salina Cruz also expands seaward from June through August. Good fishing on this ground peaks in June and ends after September.

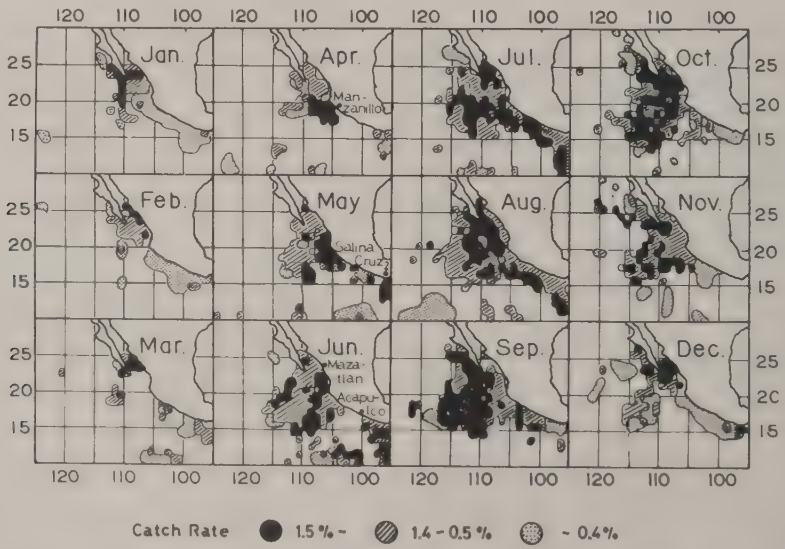
120 110 100 120 110 100 120 110 100 120 110 100
25
20
15
Jan.
Apr.
Man-zanillo
Jul.
Oct.
Feb.
May
Salina Cruz
Aug.
Nov.
Mar.
Jun.
Maza-tlan
Acapu-lco
Sep.
Dec.
Catch Rate
● 1.5%-
▨ 1.4-0.5%
◌ -0.4%

Figure 5.—Monthly distributions of mean relative abundance of striped marlin in waters off Baja California and southern Mexico for 1966-70.

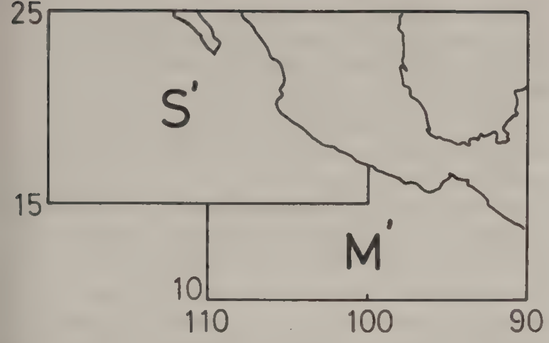

Figure 6.—Subareas selected for examination of striped marlin size composition.

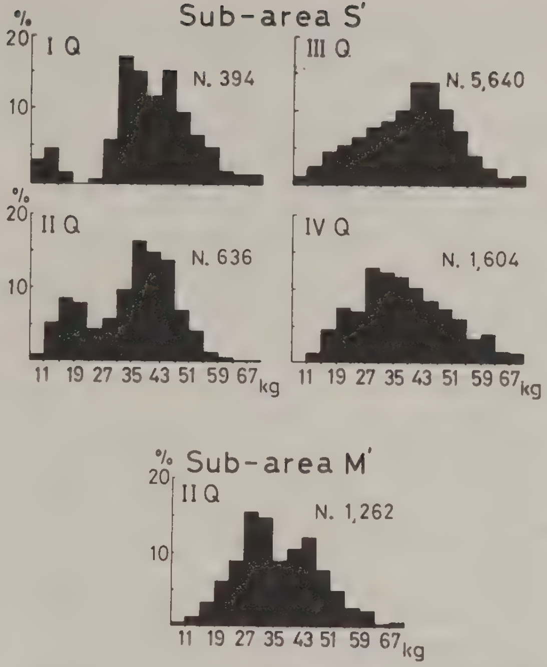

Figure 7.—Weight-frequency distributions of striped marlin in subareas S′ and M′ shown by quarters of the year.

From June, the area of good fishing off the coast from Acapulco to Mazatlán begins to expand seaward to about long. 115°W. A small, localized area of good fishing is also located at the entrance of the Gulf of California. By July, the area of good fishing has expanded seaward and along the coast and by August the good fishing grounds form a broad and continuous band throughout the waters of Baja California. The seaward expansion of good fishing continues into September and extends as far west as long. 117°W. This shift in good fishing into the offshore waters, however, is accompanied by a decline in catch rates in the more coastal waters. In October, the fishing ground becomes narrow and is located farther east. This phenomenon coincides with the decreasing trend in catch rates after October in subarea SW as shown in Figure 2. In November, the area of good fishing is narrower than in October and is divided into two areas; one is

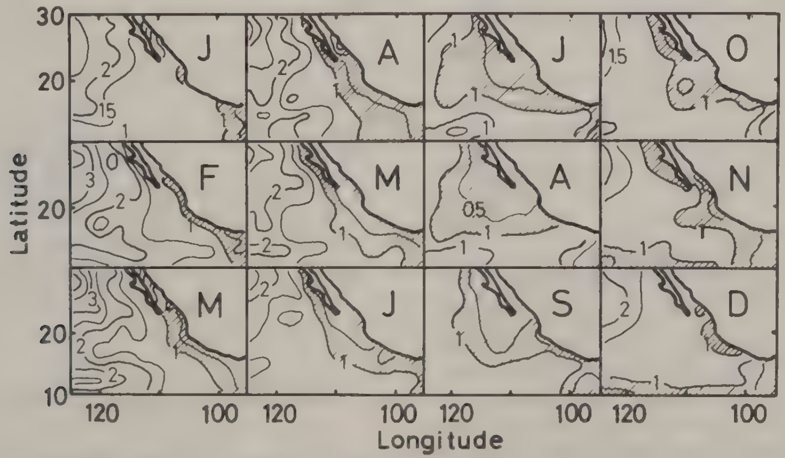

Figure 8.—Monthly thermocline topography for the eastern tropical Pacific Ocean (after Robinson and Bauer 1971). The numbers on the contour lines represent the depth to the top of the thermocline in hundreds of feet.

centered off the mouth of the Gulf of California and the other is the offshore area bounded by lat. 15°-20°N and long. 107°-115°W.

FISHING CONDITIONS IN RELATION TO THE THERMOCLINE

Figure 8 shows the monthly thermocline topography (depth to the top of the thermocline) for the eastern tropical Pacific as described by Robinson and Bauer (1971). The depth to the top of the thermocline is in general relatively shallow in the eastern tropical Pacific (Cromwell, 1958; Forsbergh and Broenkow, 1965; Sund and Renner, 1959). As shown in Figure 7, the shallow thermocline area begins to extend seaward beginning in June, extends farthest seaward from July through September, and begins contracting after October.

This pattern of expansion and contraction of the shallow thermocline area coincides fairly closely with the pattern of expansion and contraction of good fishing grounds as shown in Figure 5. It is noted that the areas of good fishing begin expanding after June in correspondence with the expansion of the shallow thermocline area. From July through September, when the shallow thermocline area is most extensive, the areas of good fishing are also most extensive. In November, when the shallow thermocline area is contracted, so is the area of good fishing. Between December and March, when the shallow thermocline area is narrowest and confined to the region around the mouth of the Gulf of California, the area of good fishing is also confined to the same small area. For example, the 100-ft contour in thermocline topography is recessed shoreward at about lat. 23°-25°N and long. 117°W in September and lat. 21°N and long. 112°W in October. In these same general areas good fishing grounds are found in a similar pattern. In November, the 100-ft contour is noticeably recessed shoreward at about lat. 20°-23°N and long. 106°W and a good fishing ground is also found with this same shape.

In order to clarify this relationship between thermocline depth and good fishing grounds, the areas with depths to the top of thermoclines shallower than 100 ft were calculated for subarea S (subareas SE and SW combined) and plotted along with average monthly catch rates in Figure 9. It is seen that the monthly catch rates increase as the index of shallow thermocline area increases. Both the catch rates and index are highest from July through October. The catch rates are also somewhat high from December through January when the index of shallow thermocline area is low. This phenomenon is caused by the fact that fishing is conducted around the mouth of the Gulf of California where the thermocline is shallow during these months.

The relationship between the depth of the thermocline and the distribution of tunas has been discussed by several workers (Brandhorst, 1958; Blackburn, 1965; Green, 1967; Suda, Kume, and Shiohama, 1969; and Kawai, 1969). According to Brandhorst (1958), an area with a high standing crop of zooplankton is generally also a region with a shallow thermocline, while an area with poor standing crop would, in general, tend to correspond with a deeper thermocline. Laevastu and Rosa (1963) suggested that thermocline ridges seem to be favorable for aggregation of tunas. As one of the factors related to the above, it is considered that a high standing crop of zooplankton would have the effect of attracting small forage organisms which in turn results in aggregating tunas.

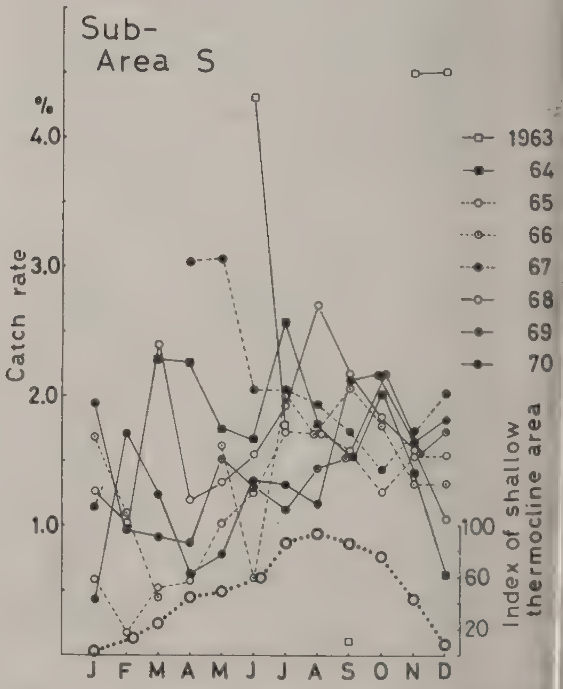

Figure 9.—Index of extent of surface areas with thermoclines shallower than 100 feet plotted against the monthl average catch rates of striped marlin for area S (include subareas SW and SE in Fig. 1).

In the waters off Baja California the thermocline is generally shallow and there is a correspondingly high standing crop of zooplankton (Brandhorst, 1958). It is likely, therefore, that the seasonal shifts in areas of good fishing for striped marlin would coincide with the expansion and contraction of the shallow thermocline areas. In other words, it seems that the formation of good fishing grounds off Baja California is related to shallow thermocline areas where there is a more abundant food supply.

Furthermore, the depth of the thermocline in lower latitudes generally coincides with the depth of the oxycline. Dissolved oxygen decreases rapidly within the thermocline and becomes virtually nonexistent below the bottom of the thermocline. Concerning the relation between fish and dissolved oxygen it was reported, for instance, that the minimum volume required by salmon is about 3 ml per liter (Tamura, 1949). Banse (1968) indicated that though the relation between fish catches and water temperatures in Arabian Sea trawling grounds is not too clear, the catches tend to fluctuate according to levels of dissolved oxygen in the bottom water layer. It is clear that the relationship between the amount of dissolved oxygen and the distribution of striped marlin should be studied as an important aspect of fishery oceanography.

ACKNOWLEDGMENT

The author is most grateful to Shoji Ueyanagi, Keiji Nasu, and Susumu Kume of the Far Seas Fisheries Research Laboratory, and Masaki Ebizuka of the Kanagawa Prefectural Fisheries Experimental Station for their helpful criticism and advice on this study. He also wishes to thank other staff members of that Laboratory for supplying the background data and for providing valuable suggestions. Grateful thanks are also extended to Tamio Otsu, National Marine Fisheries Service, Honolulu Laboratory, who kindly helped in reviewing and editing this report.

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A Review of the Longline Fishery for Billfishes in the Eastern Pacific Ocean

JAMES JOSEPH, WITOLD L. KLAWE, and CRAIG J. ORANGE[1]

ABSTRACT

Catch and effort statistics from the Japanese longline fishery are used to examine the quarterly distribution of each of the six species of billfishes taken in the eastern Pacific Ocean east of long. 130°W. Striped marlin appear to be the most widely distributed billfish in the eastern Pacific. Blue marlin are confined more to the equatorial high seas regions than the other species. Sailfish are extremely abundant within 600 miles of the shoreline along Mexico and Central America. Shortbill spearfish are relatively sparsely distributed and less abundant in inshore waters than are sailfish. Black marlin are the least widely distributed and least abundant of the billfishes in the eastern Pacific. Swordfish are abundant in waters around Baja California, Mexico and near northern Peru and southern Ecuador. They are also frequently encountered in or near the cool upwelled waters along the equator.

Trends in abundance, as reflected by catch/1,000 hooks and total catch, are discussed. On the southern grounds of the striped marlin fishery, apparent abundance of this species has dropped to about a third of its highest level, but fishing success has remained constant on the northern grounds. Catches of striped marlin reached their peak in 1968 (337,000 fish); by 1970 the catch had dropped to 180,000 fish. Apparent abundance and catches of blue marlin also decreased from levels in the early 1960's. In 1963, 75,000 blue marlin were taken but the catch decreased to about 22,000 fish by 1966 and has fluctuated about that level since. Because so few black marlin are taken in the eastern Pacific, trends in the abundance of this species are not discussed. The longline fishery for sailfish in the eastern Pacific began in a substantial way in 1965 with a catch rate of about 80 fish/1,000 hooks on the major sailfish grounds but by 1970 this had dropped to about 11 fish/1,000 hooks. Also catches on these grounds dropped from a peak of about 370,000 fish in 1965 to about 210,000 fish in 1970. Catches of swordfish contined to increase from the beginning of the fishery in the 1950's until 1969, the peak year, when about 112,000 fish were landed. Catches decreased in 1970, although effort decreased also. The apparent abundance of swordfish has shown no general decreasing trends.

A general discussion of the needs of scientific research on billfishes is given in the final section of the report.

Billfishes are distributed throughout nearly all of the temperate and tropical oceans of the world and are caught by commercial and sport fishermen. Six species of billfish occur in the Pacific Ocean. The nomenclature of billfishes has been a controversial subject for some time. For the purposes of this paper we chose to utilize the scientific nomenclature of Nakamura, Iwai, and Matsubara (1968). We also show the common names in English, Spanish, Japanese, Korean, and Chinese.

Xiphias gladius Linnaeus
- Chinese (People's Republic of China PRC): chien-yü
- Chinese (Republic of China RC): chien-ch'i-yü
- English: Swordfish
- Japanese: mekajiki
- Korean: whang-sae-chi
- Spanish: pez espada

Tetrapturus angustirostris Tanaka
- Chinese (PRC): hsia-wen-ssu-chi'i-ch'i-yü
- Chinese (RC):
- English: Shortbill spearfish
- Japanese: furajkajiki
- Korean:

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Spanish: pez aguja corta
Tetrapturus audax (Philippi)
Chinese (PRC): ch'i-tso-shih-ch'iang-yü
Chinese (RC): hung-jou-ch'i-yü
English: Striped marlin
Japanese: makajiki
Korean:
Spanish: marlin rayado
Makaira mazara (Jordan and Snyder)
Chinese (PRC): lan-ch'iang-yü
Chinese (RC): hei-p'i-ch'i-yü
English: Blue marlin
Japanese: kurokajiki
Korean: nog-saeg-chi
Spanish: marlin azul
Makaira indica (Cuvier)
Chinese (PRC):
Chinese (RC): pai-p'i-ch'i-yü
English: Black marlin
Japanese: shirokajiki
Korean:
Spanish: marlin negro
Istiophorus platypterus (Shaw and Nodder)
Chinese (PRC): tung-fang-ch'i-yü
Chinese (RC): pa-chiao-ch'i-yü
English: Sailfish
Japanese: bashokajiki
Korean: dot-sae-chi
Spanish: pez vela

The term *billfish* in this report is meant to include all of the six species listed above.

Two of the six species which occur in the eastern Pacific are widespread and rather evenly distributed throughout the Pacific Ocean. Striped marlin occur between approximately lat. 45°N and 40°S with the heaviest concentration in the eastern Pacific east of long. 115°W. The distribution of blue marlin is nearly identical to that of striped marlin; however, it is more restricted in a north-south direction, from about lat. 40°N to 35°S. The major concentration of blue marlin in the Pacific is between the equator and lat. 10°N, from long. 130°W to 145°E.

The remaining four species, although distributed widely throughout the Pacific Ocean, show a somewhat more patchy distribution. Swordfish, which extend more poleward than the other billfishes, occur between about lat. 50°N and 40°S. Black marlin, which are found between about lat. 35°N and 30°S, are most concentrated in the western Pacific and occur in high concentration only sporadically in the eastern Pacific. Sailfish and shortbill spearfish are found throughout the Pacific between about lat. 35°N and 25°S. Although there is much confusion in the catch statistics of these two species, the higher concentrations of sailfish appear to be more associated with landmasses than those of shortbill spearfish; the latter seem to be more abundant in warmer waters.

Sport fisheries for billfishes have existed in the eastern Pacific Ocean for the last 70 years. Minor commerical fisheries for some of the billfish species have existed for a long time. Striped marlin and swordfish particularly have been harvested commercially in waters off California and Mexico since about 1915 (Frey, 1971) and off Peru and Ecuador by subsistence fishermen since long before that. There were no substantial fisheries for billfish in the eastern Pacific until about 1956 when Japanese vessels first began taking billfish in large quantities. The Japanese method of fishing called longlining involves the use of long lines of gear, up to 120 km long, from which baited hooks are hung to a depth of about 80 to 200 m. Approximately 2,000 hooks are used in each operation of the gear.

The first longlining for billfish (and tunas) in the eastern Pacific was conducted by the Pacific Oceanic Fishery Investigations (POFI) of the U.S. Fish and Wildlife Service. In 1952 and 1954, 18 longline sets were made from POFI vessels (Royce, 1957).

Similar experimental fishing for billfishes was conducted by the California Department of Fish and Game (Wilson and Shimada, 1955; Mais and Jow, 1960). Striped marlin and swordfish were fished commercially until 1937 when it became illegal to land and sell striped marlin; swordfish is still a commercial species.

In 1954 and 1955, in connection with underwater nuclear tests conducted on the high seas southwest of California, four longline cruises were undertaken by the U.S. Atomic Energy Commission (AEC). These operations produced unspecified catches of billfish (Shimada, 1962). More details of these cruises are probably contained in the AEC Technical Reports Nos. WT-1013 and WT-1019 printed in 1956 but, although declassified, these reports are difficult to obtain.

All of the cruises discussed above were of a non-commercial nature. As already noted the first major commercial operation for billfish in the easter Pacific started in late 1956 when Japanese longlin vessels, which until then had been operating in th area west of long. 130°W, commenced to fish east o that meridian.

After 1956 the Japanese longline fishery in the eastern Pacific expanded rapidly and at the present this fleet is fishing in all areas of the eastern Pacific in which billfish and tunas are found.

In addition to their commercial longline operation, the Japanese used longline gear to investigate the complex oceanic environment during a number of scientific cruises devoted to fishery biology and exploratory fishing. The results of these investigations are well documented in trade as well as scientific journals. Some of the latter are: Suda and Schaefer, 1965; Kume and Schaefer, 1966; Kume and Joseph, 1969a and 1969b; Anonymous, 1972.

Commercial longline vessels of the Republics of Korea and China also fish for billfish in the eastern Pacific. The vessels of these two countries first began their operations in the eastern Pacific in the mid-1960's. Documentation of these fisheries is not complete and statistical coverage is low (Anonymous, 1968a, 1970a, and 1971a).

In 1965 the U.S.S.R. conducted two longline cruises in the eastern Pacific, mostly in the Gulf of Tehuantepec, Mexico. Results are given in Chernyi (1967); Novikov and Chernyi (1967); and Yurov and González (1971). The latter report also discussed the results of a Cuban longline expedition for billfishes and tunas in the eastern Pacific in 1967 (Bravo and González, 1967).

During Cruise 14 of the RV *Anton Bruun*, operated by the U.S. National Science Foundation, longlining was conducted off Chile and Peru in 1966 (Shomura)[2].

Experimental longline fishing for swordfish off California and Mexico was conducted by the U.S. Bureau of Commercial Fisheries in 1968. Results of these investigations were given by Kato (1969).

Most recently, in 1970, personnel of the Scripps Institution of Oceanography conducted experimental longline fishing for tunas and billfish in the eastern Pacific Ocean to the west of Baja California (Blackburn, Williams, and Lynn)[3].

In this report the literature mentioned above is utilized to discuss the distribution of billfishes in the eastern Pacific Ocean. Data on catch and effort for the Japanese longline fishery, which captures approximately 85% of the billfish taken in the eastern Pacific, are used to study trends in relative abundance, effort, and catch. In the final section problems relevant to scientific research on billfish are discussed.

THE DATA—SOURCES AND PROCESSING

The major source of the information used in this report is from the Japanese longline fleet. These vessels maintain logbook records of their fishing operations which are submitted to the Fisheries Agency, Ministry of Agriculture and Forestry, Japan. The data are printed each year in the Annual Reports of Effort and Catch Statistics of the Research Division, Fisheries Agency of Japan (Anonymous 1968b, 1969b, 1970b, 1971b, and 1972). Catches expressed in numbers of fish are reported by species, areas of 5 geographical degrees on a side, month, type of operation, size of vessel, type of bait utilized, number of sets and number of hooks. Data from 1966 through 1970 (Anonymous, 1968b, 1969b, 1970b, 1971b, and 1972) were taken from the Fisheries Agency's Annual Reports; prior to that time the reports of Suda and Schefer (1965), Kume and Schaefer (1966) and Kume and Joseph (1969a), were used. Details of data collection, handling, and logbook coverage are given in these reports.

All logbook catch and effort data were stored on magnetic tape and then used to generate tabulations of catch and effort in convenient format for analysis.

In order to compute total catch for the Japanese longline fishery, the recorded logbook catch was adjusted by the reciprocal of the percent coverage which the logbooks represented of the total catch. These percentages, which vary between 60 and 90, are given in the relevant reports listed above.

The saury *(Cololabis saira)* has been the principal bait used by the Japanese longline fishery but in recent years there has been increased use of other types of bait. Since 1964 some of the vessels operating off the west coast of Baja California, Mexico have used squid *(Todarodes pacificus)* for bait. At least through 1966 these vessels were fishing mainly for swordfish, usually at night. It is unknown whether this type of fishing was done subsequent to

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[2] Shomura, R. S., unpublished report. Cruise Report, Research Vessel *Anton Bruun*, Cruise 14. Special Report No. 4, Marine Laboratory Texas A&M University, Galveston, Texas, 38 pp. (pages 7 through 38 not numbered). 1966.

[3] Blackburn, M., F. Williams, and R. Lynn, unpublished report. The bluefin tuna approach region off Baja California. pp. 17-19 in: Progress Report—Scripps Tuna Oceanography Research (STOR) Program—Report for the year July 1, 1969 - June 30, 1970. Univ. Calif., Scripps Inst. Oceanogr., IMR Ref. (71-3), SIO Ref. 70-32:24 pp. 1970.

1966. Catch rates of swordfish taken by the modified gear at night are generally different from the catch rates resulting from standard gear; the reader is referred to Kume and Joseph (1969a) for a discussion of this difference. In this report no distinction is made between day and night fishing.

Data on the longline catches of the Republics of Korea and of China are from the official reports of the respective fisheries agencies of these countries (Anonymous 1968a, 1969a, 1970a, 1971a). These data have not been included in the charts and graphs presented in this report because the amount that they represent of the total catch is extremely low and highly variable. During 1969 the Korean and Chinese catch of billfish in terms of weight amounted to less than 5% of the total longline catch of billfish from the Pacific Ocean.

OVERALL TRENDS IN CATCH AND EFFORT

When Japanese longline vessels first began fishing in the eastern Pacific in 1956, effort was restricted to a narrow region on either side of the equator extending eastward only as far as about long. 120°W (Fig. 1). Effort increased rapidly between lat. 10°N and 10°S of the equator, and by 1961 fishing extended eastward to long. 90°W (Suda and Schaefer, 1965). By the end of 1963 it had reached the mainland of South America (Kume and Schaefer, 1966). It then began to expand rapidly poleward and by 1966 fishing was conducted in almost the entire region bounded by long. 130°W and the continents and lat. 35°N and 40°S (Kume and Joseph, 1969a). Since 1968 the distribution of effort has remained relatively constant.

The first fishing effort by the Republic of China east of long. 130°W occurred in the mid-1960's. It has remained rather restricted to the area east of long. 115°W and lat. 5°N and 30°S. Korean vessels fish primarily between long. 130°W-110°W and lat. 5°S-40°S.

In order to examine trends in catch rates within areas for which there is a continuous time series of catch and effort statistics, we have divided the eastern Pacific into the 18 areas defined by Kume and Joseph (1969a). These areas represent expansions in the distribution of effort generated throughout the fishery (Fig. 1).

Annual estimates of total effort for the Japanese longline fishery are shown in Figure 2. These estimates, expressed in millions of hooks set per year within the eastern Pacific Ocean east of long. 130°W, have been adjusted to represent complete coverage. From a low level of about 3.5 million hooks set prior to 1960, effort increased rapidly to more than 60 million hooks by 1964. Since 1964, effort has varied around 50 million hooks set per year. Although the number of hooks set is proportional to the total fishing effort exerted in the eastern Pacific it is not proportional to the actual number of longline sets made because there has been an increasing trend in the average number of hooks utilized per set (Fig. 3). Whereas in the mid-1950's about 1,900 hooks were used per set, in recent years about 2,200 hooks per set have been used. For this reason, in the subsequent analysis, catch per hook will be used as an index of apparent abundance rather than catch per set. For such analysis it is assumed that the spacing of hooks on

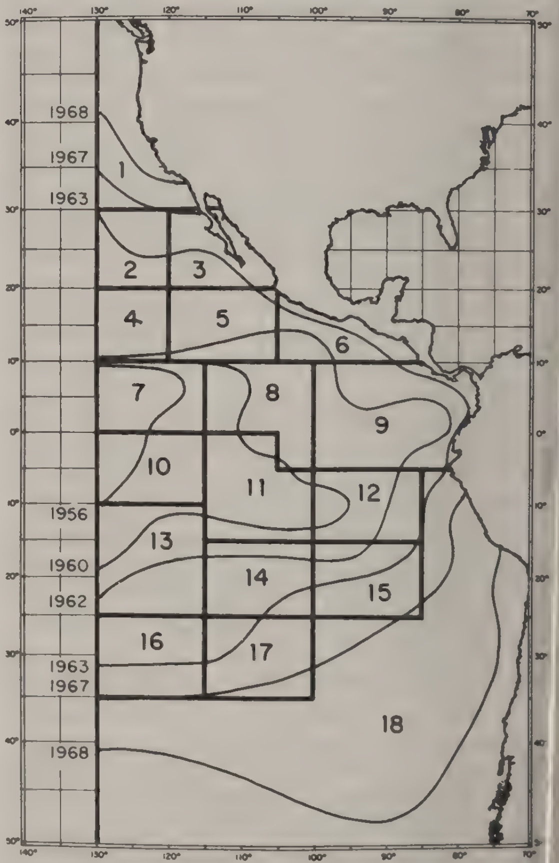

Figure 1.—Expansion of the Japanese longline fisher into the eastern Pacific Ocean and designation of are for analytical purposes.

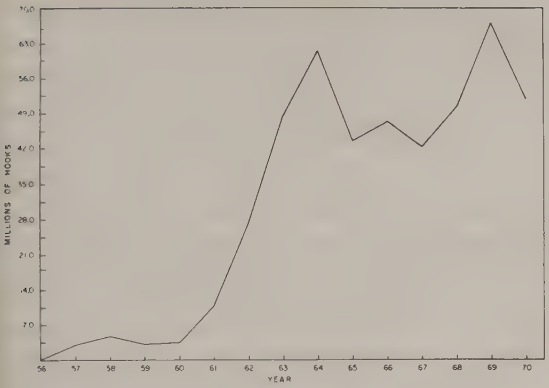

Figure 2.—Annual estimates of total longline effort for the Japanese longline fishery in terms of millions of hooks set in the eastern Pacific during 1956-1970.

the line does not appreciably affect the catchability of a single hook, although we have not tested this.

When the Japanese longliners first began fishing in the eastern Pacific their catches were nearly all tuna (Fig. 4) because very high catch rates of tuna were common in the area in which they operated. As effort increased catch rates of tunas began to decrease rather quickly (Fig. 5). At the same time the demand for billfish (except swordfish) increased as a result of the rapid development of the fish sausage and fish ham industry in Japan. The most important ingredients for fish ham and sausage were sailfish and marlin. Another important development related to the billfish fishery took place in about 1966; as Ueyanagi (1972) explains, "Raw meat of striped marlin is considered to be the best quality of billfishes and its price equals that paid for the flesh of the more expensive tunas. The meat of billfishes, however, did not always command high prices. It is only since about 1966 that the price has increased remarkably. This can be attributed to the advancement in freezing techniques; in 1966 rapid deep freezing facilities became a standard part of new fishing vessels. This processing method had a great influence on the demand for the flesh of billfishes in Japan, which almost overnight began to be consumed as 'sashimi' (raw fish) just as are the other tunas." In response to the increased demand and higher prices for billfish as well as the decreasing catch rates for tunas, the fishery expanded during the early 1960's rapidly towards the north and northwest where greater concentrations of striped marlin were found. The northward expansion continued through the mid-1960's and increased catches of marlin were made; additionally the fishery expanded shoreward onto the sailfish grounds. From Figure 4 it is clear that after 1965 almost half the total catch was comprised of billfish whereas prior to that time most of it was made up of tunas. The catch of tunas decreased from a peak of about 1.45 million fish to the present average level of about 0.75 million fish. Catch rates for tuna have likewise decreased by about one-half the initial average levels.

The total catch of billfish, as noted, began to increase at about the time catch rates of tunas dropped off in 1962 and has continued to increase to the present average level of about 0.6 million fish per year.

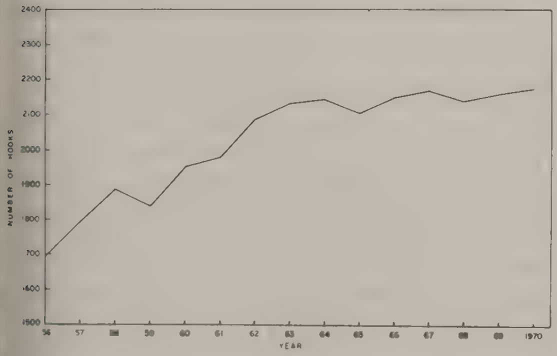

Figure 3.—Annual average number of hooks per set.

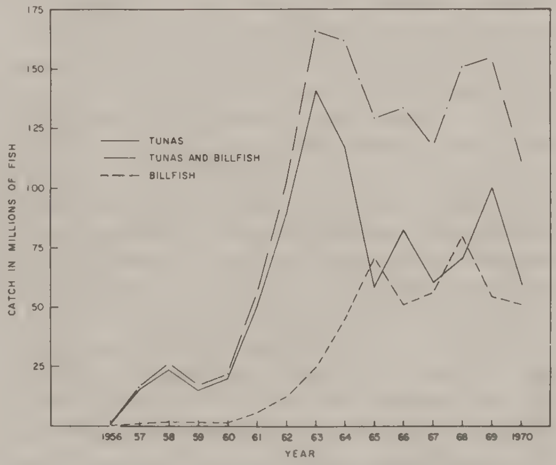

Figure 4.—Total annual catch of tuna and billfish, in millions of fish, by Japanese longline vessels in the eastern Pacific.

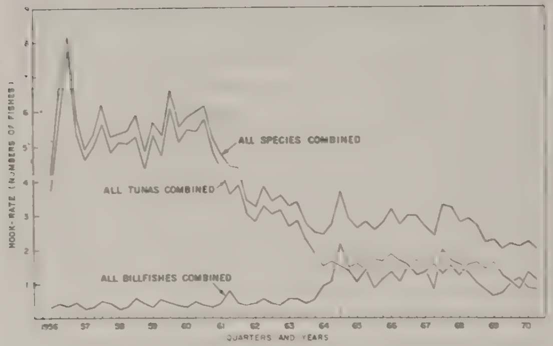

Figure 5.—Annual average catch per 100 hooks of tunas and billfishes by Japanese longline vessels in the eastern Pacific.

It is interesting to note in Figure 5 that the total catch rate, which leveled off in about 1964, is comprised of about half tunas and half billfish. It is pointed out here that both the catch figures and the catch per effort figures are expressed in terms of number of fish rather than weight. If statistics based on weight were available these trends would be somewhat different. It should also be mentioned that Figures 4 and 5 do not include data for the Korean and Chinese catches and effort. However since their catches are rather minor relative to those of the Japanese, this fact should not alter the results very much.

The total annual catches of billfish and tuna taken by Japanese longliners in the eastern Pacific are shown by species, in Figure 6. In the billfish category, sailfish and shortbill spearfish are combined in one histogram for the reasons noted earlier and they represent the greatest catches in terms of numbers. The numbers of striped marlin caught follow closely behind sailfish and shortbill spearfish and in terms of weight far exceed them. The catches of the other species, swordfish, blue marlin and black marlin, are much less. All of the species except swordfish showed a rapid increase to some maximum, followed by a great deal of variability at a somewhat lower average level.

With respect to tunas, bigeye was the most abundant species in the catch, followed by yellowfin, albacore, skipjack, and bluefin. The catches of skipjack and bluefin are extremely low and can be considered incidental.

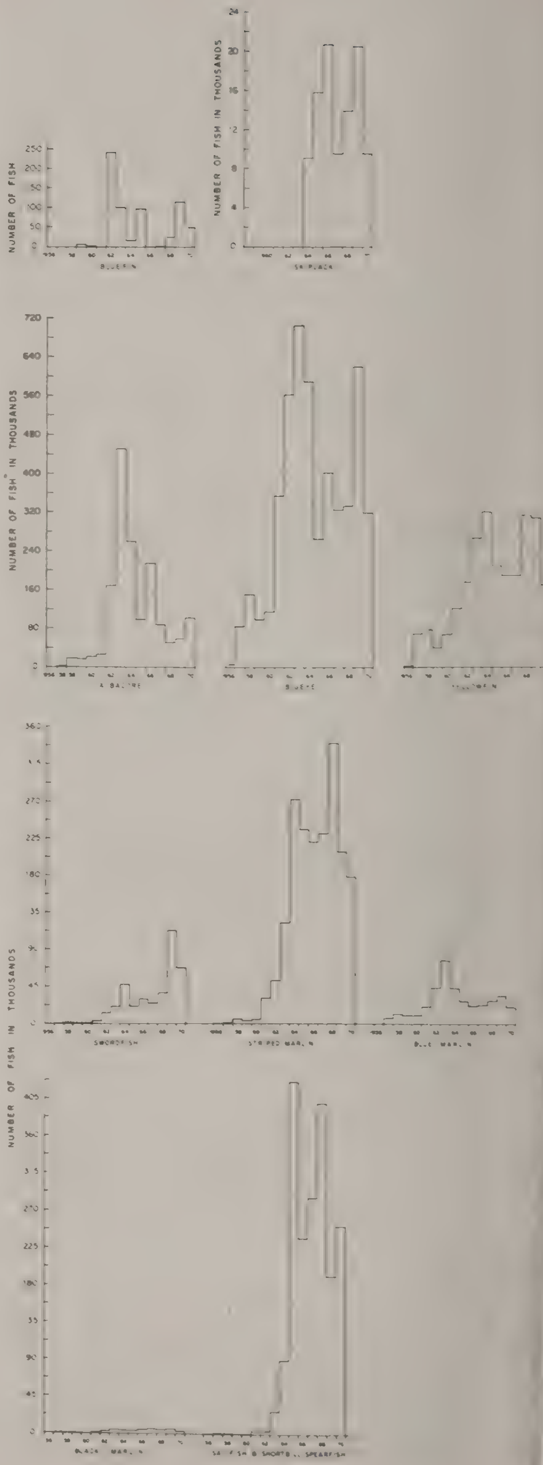

Figure 6.—Total annual catch by species of tunas and marlins captured by Japanese longline vessels in the eastern Pacific.

As with billfish, catches of tunas increased rapidly to a peak then fluctuate about some slightly lower level.

ANALYSIS AND RESULTS

Geographical Distribution

The average quarterly catch rate of billfish is shown by species within 5-degree areas in Figures 7 through 12, for the years 1956-1970. Catch rate is expressed in numbers of fish caught per 1,000 hooks. Such figures provide a useful basis for examining the quarterly average distribution of the longline-caught billfish. If catchability is assumed to be constant, then shifts in centers of billfish abundance[4] can be utilized to infer migratory behavior.

Striped Marlin

The catch and effort statistics show striped marlin to be widely distributed throughout the eastern Pacific Ocean during all seasons of the year, occurring from about lat. 35°N to 40°S to the coastline of the Americas (Fig. 7). The areas of high relative density which occur near shore are variable among quarters.

During the first quarter highest hook rates are near the Revillagigedo Islands, the tip of Baja California, and in the Gulf of California. These expand southward and westward during the second quarter and third quarter. By the end of the third quarter the area of high relative abundance has extended southward to lat. 10°N and westward to long. 130°W. It is during this period when the highest densities of striped marlin in the eastern Pacific are encountered, centered in the area bounded by long. 125°-110°W and lat. 15°-25°N. During the fourth quarter the area of high marlin abundance diminishes and the striped marlin appear to be found nearer shore. A slight displacement northward of the high hook rates from about lat. 25°N to 30°N is observable during the third and fourth quarters, most likely associated with the movement of warmer water northward.

In the southern area of the fishery striped marlin are relatively abundant as far south as lat. 35°S during the first quarter of the year. This period represents the southern summer, when warmer waters are displaced southward. As southern waters begin to cool at the onset of the southern winter, the southern boundary of the distribution is displaced northward. This continues through the third quarter during which relatively few striped marlin are found below lat. 20°S. During the fourth quarter as the southern summer begins, striped marlin commence to move southward and are again found below lat. 30°S.

Also during the first quarter of the year striped marlin appear to be abundant around the Galapagos Islands and off Colombia and Ecuador. There also seems to be an area of high concentration in the offshore region bounded by lat. 10°-15°S and long. 85°-100°W. During the second quarter there appears to be a general decrease in abundance. However there is a suggestion of a southerly shift in the highest concentration of fish that continues through the third quarter at which time the highest concentrations south of the equator are in the general region of long. 95°-115°W and lat. 15°-25°S. By the fourth quarter the areas of greatest abundance are again around the Galapagos and off South America. This pattern of changes in the distribution of marlin suggests a shoreward migration during the southern summer and an offshore migration during the southern winter.

In an earlier publication Kume and Joseph (1969a) compared the available data from subsistence and sport fisheries with those from the longline fisheries. They concluded that the seasonal distribution of striped marlin as reflected by sport and subsistence fisheries corresponds well with that inferred from commercial longline catches.

As already noted, striped marlin are found throughout the Pacific Ocean but their abundance is much greater in the eastern half than in the western half of the Pacific. An area of high abundance also occurs in the region bounded by lat. 15°N to 25°N and long. 130°W to 175°E. Whether more than one subpopulation of striped marlin exists is not known. On the basis of their analysis, Kume and Joseph (1969a) noted that it seemed unlikely that striped marlin in the eastern Pacific are comprised of more than a single stock. They did not comment, however, on the relationship of the stock in the eastern Pacific to those farther west.

Blue Marlin

Blue marlin are captured by longline vessels in the eastern Pacific between approximately lat. 30°N and 35°S (Fig. 8). In the northern areas the distribution of blue marlin does not appear to fluctuate seasonally but in the southern areas there appears to be a slight shift to the south during the southern summer, particularly in the first quarter of the year.

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[4] Throughout the report "abundance" refers to "apparent abundance."

Only one general area of high abundance of blue marlin occurs in the eastern Pacific, that is in the south between lat. 15°-25°S and long. 110°-130°W, and during the southern summer. Catches of this species in the rest of the eastern Pacific are quite low except for sporadic good catches in the Panama Bight.

Few blue marlin are taken in the sport and subsistence fisheries of the eastern Pacific and therefore not much data are available on the distribution of

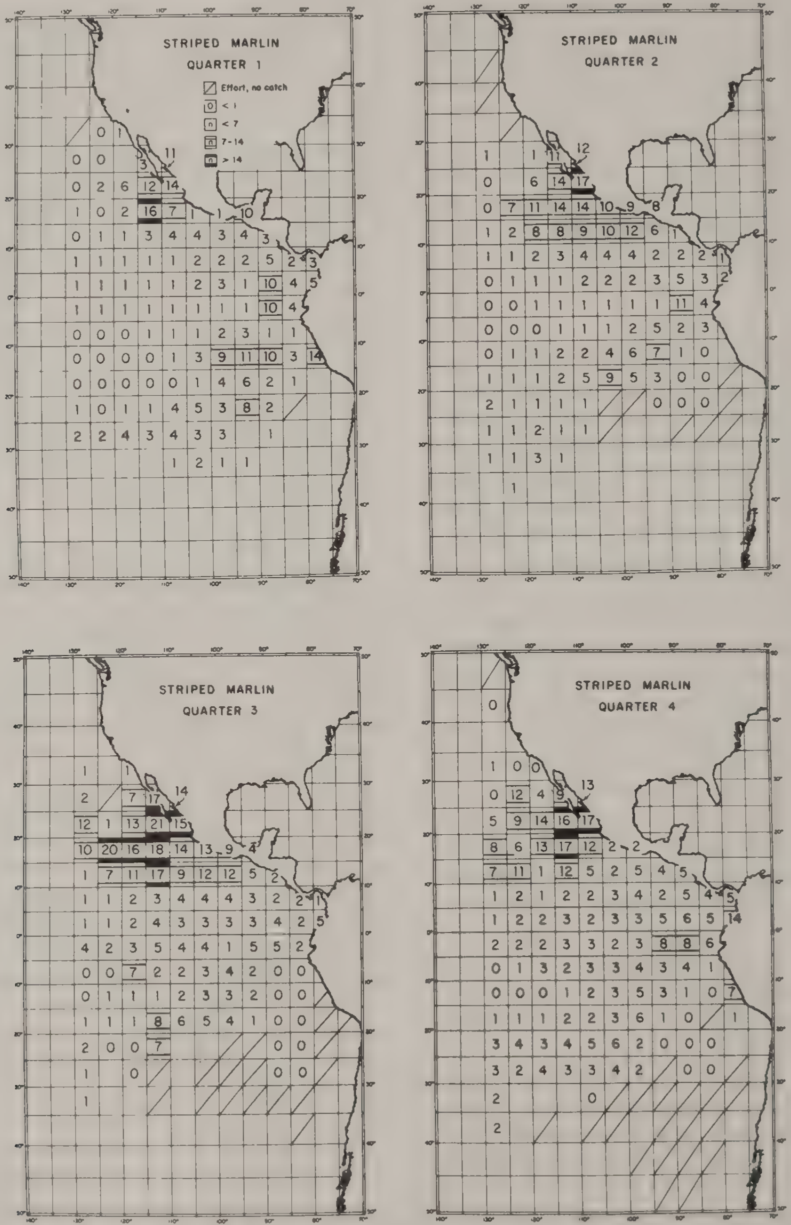
STRIPED MARLIN
QUARTER 1
▨ Effort, no catch
0 < 1
n < 7
n 7-14
n > 14
STRIPED MARLIN
QUARTER 2
STRIPED MARLIN
QUARTER 3
STRIPED MARLIN
QUARTER 4

Figure 7.—Average number of striped marlin caught per 1,000 hooks by Japanese longline vessels in the eastern Pacific by quarters, 1956-1970, by 5-degree areas. **a.** First quarter. **b.** Second quarter. **c.** Third quarter. **d.** Fourth quarter.

this species from those fisheries. Sport catches of blue marlin have been reported by Rivas (1956) from Baja California, Acapulco, Mexico, and Piñas Bay, Panama. Sport catches have also been reported off Ecuador (Anonymous, 1955) and off Peru (Morrow, 1957).

Blue marlin occur throughout the Pacific Ocean but their abundance is generally greater in the western and west-central Pacific than in the eastern Pacific, apparently the reciprocal of the distribution of striped marlin. During the southern spring there appears to be a shift in the area of highest hook

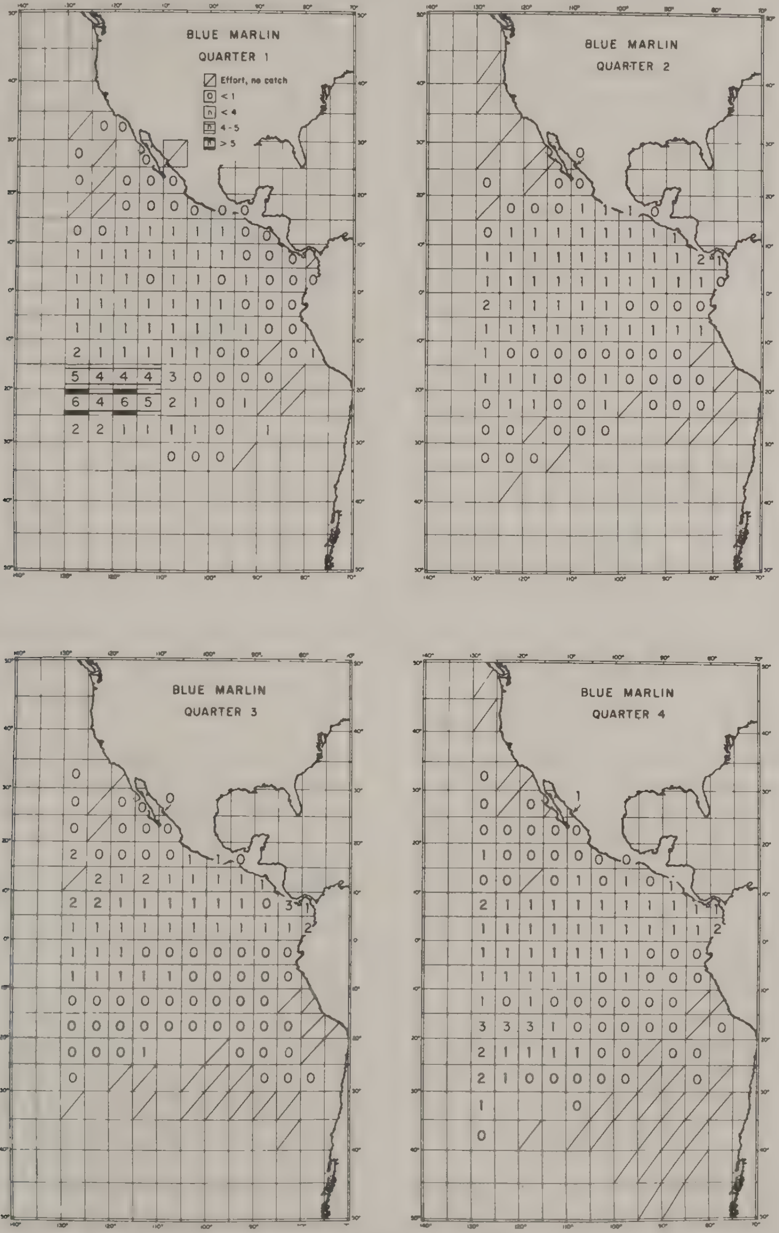
BLUE MARLIN
QUARTER 1
Effort, no catch
< 1
< 4
4 - 5
> 5
BLUE MARLIN
QUARTER 2
BLUE MARLIN
QUARTER 3
BLUE MARLIN
QUARTER 4

Figure 8.—Average number of blue marlin caught per 1,000 hooks by Japanese longline vessels in the eastern Pacific by quarters, 1956-1970, by 5-degree areas. **a.** First quarter. **b.** Second quarter. **c.** Third quarter. **d.** Fourth quarter.

rates from the northwest-central Pacific to the southeast Pacific. Hook rates remain high in the southeast through the southern summer, then shift northward again in the southern fall. It is the southeastern shift in apparent abundance which contributes to the high catch rates in the eastern Pacific area of lat. 15°-25°S, long. 110°-130°W during the southern summer.

On the basis of the distribution data examined in this report it would be impossible to determine whether the blue marlin of the eastern Pacific are from a single stock which is separate from those farther west. However Anraku and Yabuta (1959), who examined more extensive information, considered the blue marlin of the Pacific to be a single population which undergoes widespread intermingling.

Black Marlin

Black marlin are caught in negligible quantities in the eastern Pacific Ocean. Their greatest abundance is in the southwestern part of the Pacific Ocean near eastern Australia and New Guinea. Their abundance decreases rapidly toward the east, and is very low east of long. 150°W. Hook rates in the eastern Pacific are consistently less than one fish/1,000 hooks.

Because of the low catch rates in our area of study quarterly charts are not shown for black marlin. However an average annual distribution of hook rates by 5-degree areas for the years 1956-1970 is shown in Figure 9. The area in which black marlin are generally captured in the eastern Pacific can be defined as that area lying within a diagonal line extending from about the middle of Baja California southwest to where the 130th meridian intersects the lat. 20°N line of latitude, and a diagonal line extending from the Peruvian shore at about lat. 10°S to where the 130th meridian is intersected by the lat. 35°S line of latitude.

Howard and Ueyanagi (1965) discuss the general distribution of black marlin throughout the Pacific and Indian Oceans. For the eastern Pacific they utilize information from subsistence and sports fisheries to describe the nearshore seasonal distribution.

They report black marlin to occur as far south as northern Chile and in the north to about Cape San Lucas. In their discussions of the population structure they consider the black marlin of the eastern Pacific to be a separate stock from those farther

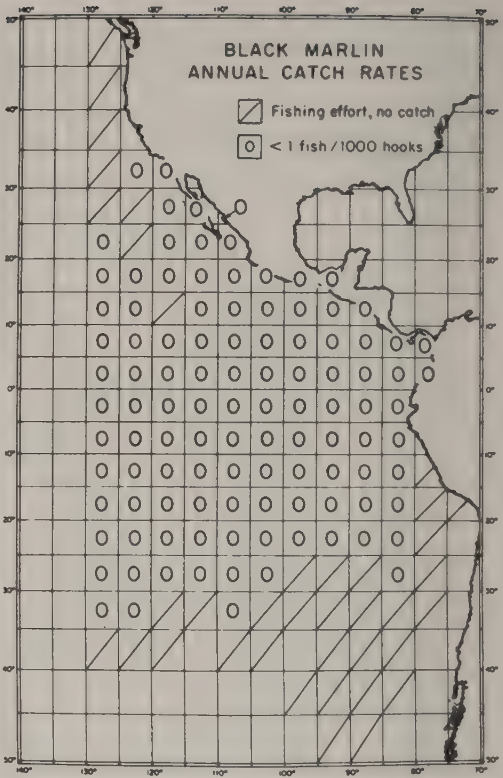

Figure 9.—Annual average number of black marlin caught per 1,000 hooks by Japanese longline vessels in the eastern Pacific by 5-degree areas, 1956-1970.

west. They also suggest that the fish which occur off southern Peru and northern Chile may be distinct from those taken near shore but farther north.

Sailfish and Shortbill Spearfish

The quarterly distribution of sailfish and shortbil spearfish is shown in Figure 10, averaged over th years 1956-1970. These two species are not separated in the figure because most commercial longline vessels do not differentiate between them i their catch records. Some idea of the relative di tribution of the two species can be obtained, hov ever, by examining the results of exploratory ar research cruises in the eastern Pacific Ocean. Du ing such cruises the two species are differentiated catch records. In their analysis of the billfish fishe of the eastern Pacific, Kume and Joseph (1969 1969b), used the results of nine exploratory cruis to differentiate the geographical distribution of t two species. In Figure 12, we have utilized the data presented by Kume and Joseph (1969a, 1969b) as well as data from Royce (1957), Mais and Jow (1960), Shomura[2], and Anonymous (1970c), to plot the distribution of sailfish and shortbill spearfish by 5-degree areas. The sailfish comprise nearly 100% of the catch of the two species shoreward of a line drawn from the intersection of lat. 10°N and long. 115°W to the intersection of lat. 5°S and the coast of Peru. As one moves seaward of that diagonal the

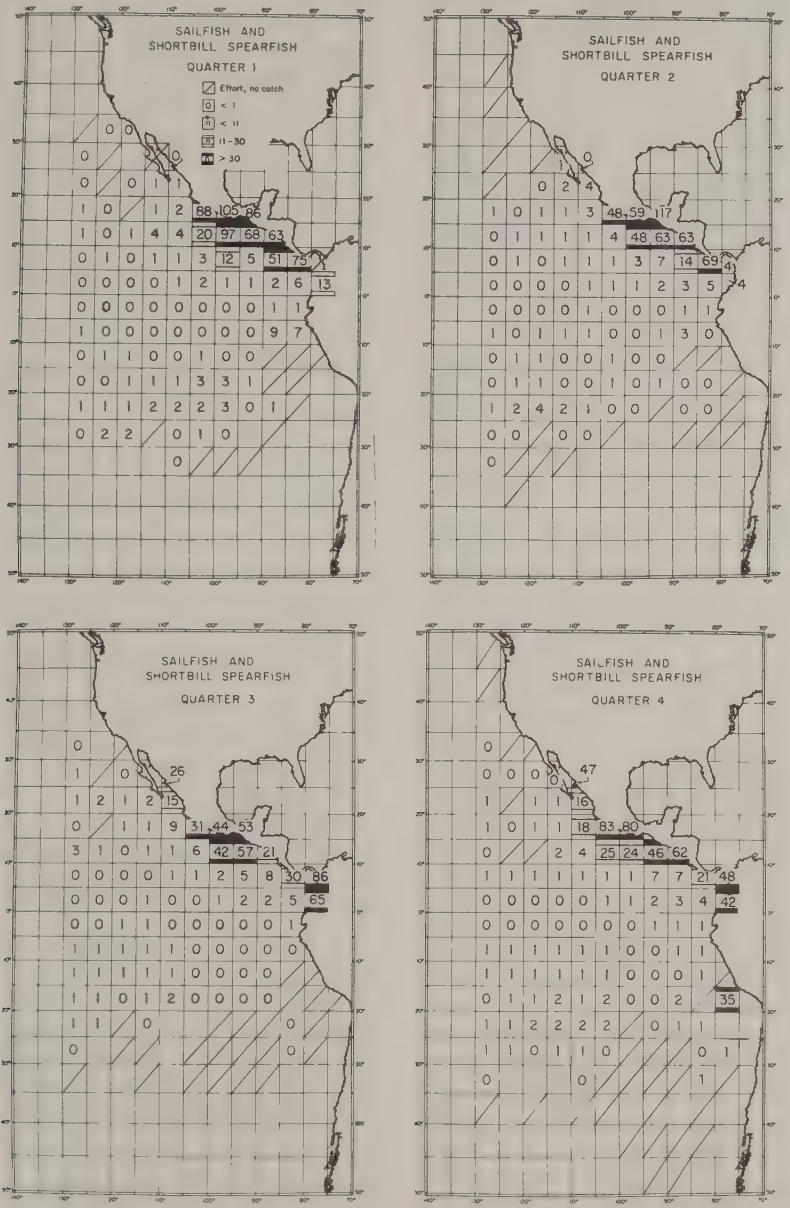
SAILFISH AND SHORTBILL SPEARFISH QUARTER 1
Effort, no catch
< 1
< 11
11-30
> 30
SAILFISH AND SHORTBILL SPEARFISH QUARTER 2
SAILFISH AND SHORTBILL SPEARFISH QUARTER 3
SAILFISH AND SHORTBILL SPEARFISH QUARTER 4

Figure 10.—Average number of sailfish and shortbill spearfish caught per 1,000 hooks by Japanese longline vessels in the eastern Pacific by quarters, 1956-1970, by 5-degree areas. **a.** First quarter. **b.** Second quarter. **c** Third quarter. **d.** Fourth quarter.

species composition changes rapidly to shortbill spearfish.

Turning again to Figure 10 it is apparent that sailfish are encountered all along the coastal waters of the Americas between about lat. 30°N and lat. 30°S. They are extremely abundant along the coast of central and southern Mexico and Central America, reaching their greatest abundance throughout the winter months between lat. 20°N and the equator. There appears to be a movement of fish northward with the displacement of warm waters to the north during the summer and fall. During the southern

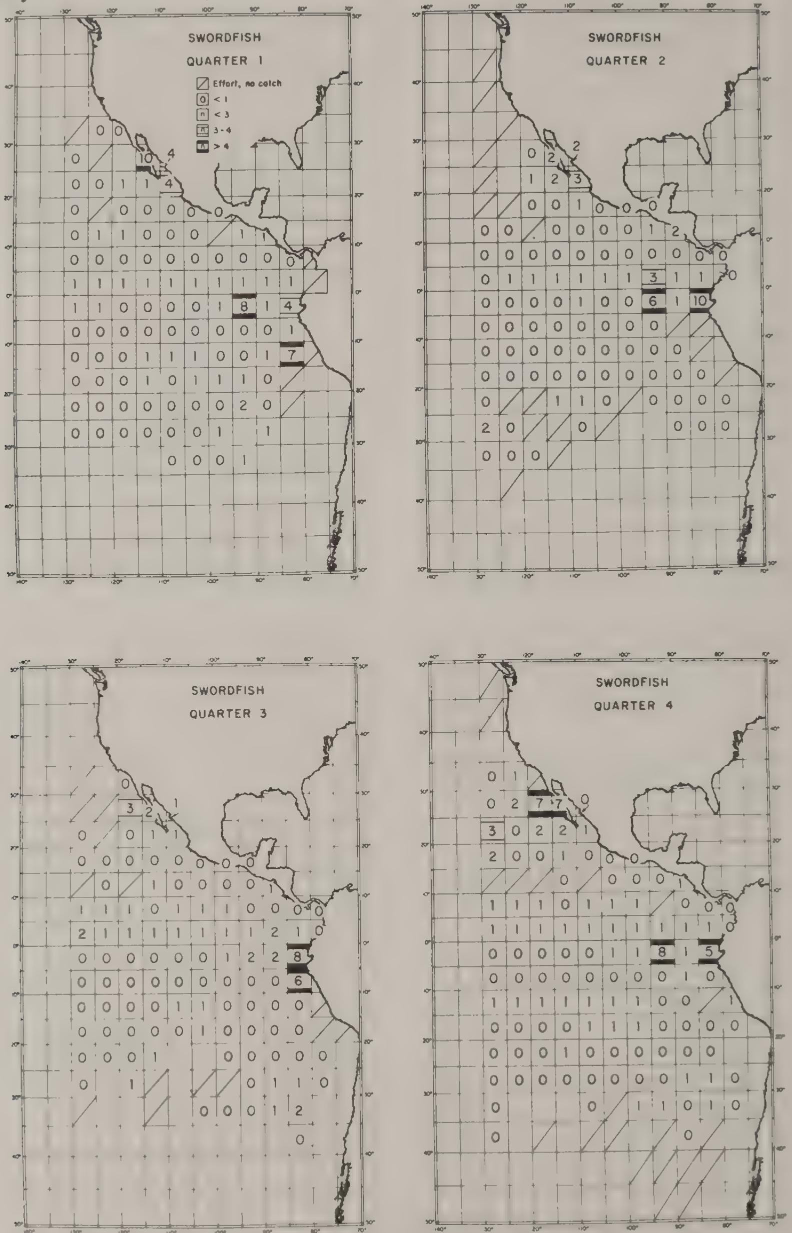
SWORDFISH
QUARTER 1
Effort, no catch
< 1
< 3
3 - 4
> 4
SWORDFISH
QUARTER 2
SWORDFISH
QUARTER 3
SWORDFISH
QUARTER 4

Figure 11.—Average number of swordfish caught per 1,000 hooks by Japanese longline vessels in the eastern Pacific by quarters, 1956-1970, by 5-degree areas. **a.** First quarter. **b.** Second quarter. **c.** Third quarter. **d.** Fourth quarter.

spring there is an apparent southward shift in the distribution of sailfish, with a normally high abundance in the 5-degree area between lat. 15-20°S and long. 75-80°W.

These current data differ from those presented by Kume and Joseph (1969a) in that high abundance is shown to occur all along the Panama Bight to as far south as the equator. This difference is due to the fact that the longline vessels did not operate in the inshore areas of the Panama Bight until after 1966; the study of Kume and Joseph included data only through 1966.

Howard and Ueyanagi (1965) have reviewed the distribution of sailfish in the eastern Pacific based on catch records from subsistence and sport fisheries. Our conclusions are consistent with theirs.

As noted above, the distribution of sailfish on an oceanwide scale decreases sharply to the west of about long. 110°W and is relatively low throughout the central Pacific. However in the western Pacific they are again found in abundance around the Indo-Pacific land masses. Whether the sailfish of the eastern Pacific are of the same genetic population as those in the western Pacific has not been determined. Because of their propensity to associate with land masses and due to their discontinuous distribution, it would seem useful to consider them as separate stocks from the point of view of fishery dynamics.

As already noted, beyond about 1,000 miles from the coastline catches of sailfish decrease rapidly and this species is replaced in the catches by shortbill spearfish.

Though shortbill spearfish are found throughout the Pacific Ocean their distribution appears to be patchy and they do not appear to be highly abundant anywhere.

Shortbill spearfish seem to occur in the catch during every quarter of the year (Fig. 10 and 12). Throughout the central eastern Pacific they are taken in low numbers. The only area in which they appear to be relatively more abundant is along lat. 20°S between about long. 130°W and 90°W. This center of abundance exhibits a southerly shift during the southern summer.

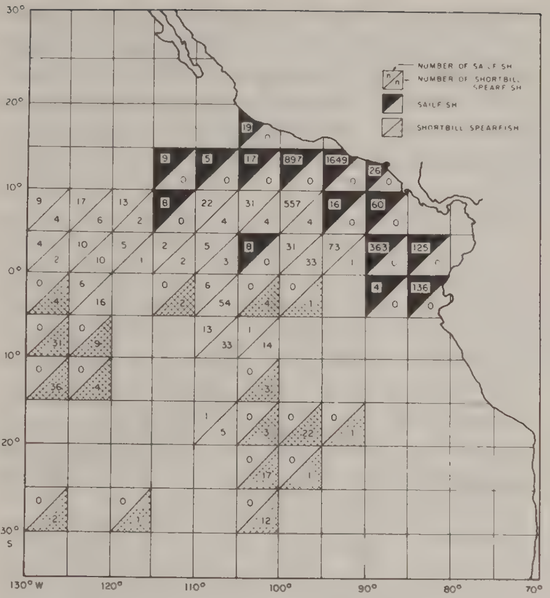

Figure 12.—Relative distribution by 5-degree area of sailfish and shortbill spearfish, 1952-1959.

Swordfish

The average, quarterly distribution of swordfish taken per 1,000 hooks is shown in Figure 11, by 5-degree areas. These hook rates do not distinguish between sets of the longline made at night and sets made during the day. Kume and Joseph (1969a) have shown that night sets are more efficient for capturing swordfish than day sets. Since night sets are generally made on the swordfish grounds, at least for 1964 through 1966, Figure 11 may be somewhat biased because catches on the swordfish grounds would be overestimated relative to swordfish catches in other areas. The bias thus introduced would not likely be great enough to make a significant difference in any inferences drawn from the figures.

In the eastern Pacific, swordfish are caught between lat. 35°N and 40°S. In the north, the best swordfish fishing is found in the coastal areas between about lat. 20°N and 30°N. The 5-degree areas adjacent to the peninsula of Baja California consistently yield the highest catch rates in the north. The principal swordfish grounds in the south are centered in the coastal waters from the equator to about lat. 15°S, and around the Galapagos Islands. From this southern area relatively consistent concentrations of swordfish extend westward in a latitudinal band along the equator during all seasons of the year. During the first and fourth quarters (southern summer) a secondary latitudinal band extends westward between lat. 10°S and 20°S. This could be explained by a migration of fish from the inshore areas; the inshore areas show a high abundance of swordfish during the second and third quarter but lower abundance during the first and fourth quarters. Kume and Joseph (1969b) have postulated that such an offshore movement is associated with a spawning migration.

Spatio-Temporal Distribution of Species Complexes

Tunas and billfishes are highly evolved, apex predators. Their life histories are rather similar in that these fishes are pelagic at all stages of their life,

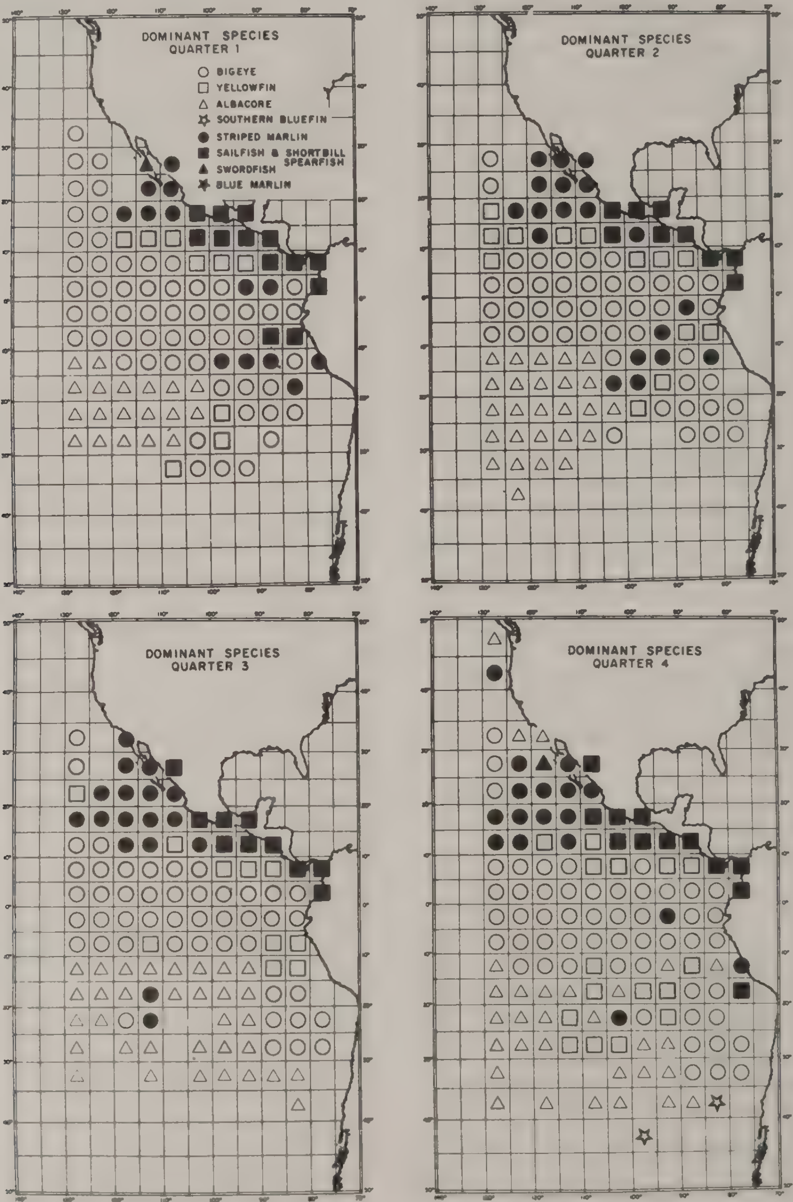
DOMINANT SPECIES
QUARTER 1
○ BIGEYE
□ YELLOWFIN
△ ALBACORE
☆ SOUTHERN BLUEFIN
● STRIPED MARLIN
■ SAILFISH & SHORTBILL SPEARFISH
▲ SWORDFISH
★ BLUE MARLIN
DOMINANT SPECIES
QUARTER 2
DOMINANT SPECIES
QUARTER 3
DOMINANT SPECIES
QUARTER 4

Figure 13.—Dominant species of tuna and billfish in the eastern Pacific by quarters, averaged for the years 1956-1970, by 5-degree areas. **a.** First quarter. **b.** Second quarter. **c.** Third quarter. **d.** Fourth quarter.

grow very rapidly, and are highly fecund. They most likely compete for the same kinds of food and, to some extent, living space and the billfishes prey on tuna. Tunas and billfishes are caught in the same areas at the same time; it is not unusual to capture five or six different species of tuna and billfish on the same set of the longline gear.

Because of the close relationship of these species it is important to understand their community structure. Such information is a necessary antecedent to the rational utilization of billfish resources. In order to examine the community structure of tunas and billfish in the eastern Pacific, as reflected by longline catches, in terms of the dominant species in the catch we have prepared Figures 13 and 14. For the purposes of this examination the species exhibiting the highest hook-rate in each time-area stratum is considered the dominant species in the catch. We have prepared two sets of data. The first set (Fig. 13) includes all of the tunas and billfishes as a community, and the dominant species is whichever one, tuna or billfish, exhibits the highest hook rate. The dominant species are shown by quarter of the year and 5-degree area.

In the second set of data only the billfishes are considered as members of the community. In this case the dominant species is that species of billfish which exhibits the highest hook rate within a time-area stratum. The dominant species of billfish in the catch is shown by 5-degree area and quarter (Fig. 14).

Tunas and Billfishes

Of the eight species examined in Figure 13, bigeye tuna appears to dominate throughout all four quarters of the year. In each quarter they are dominant between about lat. 10°N and 10°S and eastward to about long. 100°W. East of long. 100°W they are dominant generally between about lat. 5°N and 5°S to the mainland. These limits appear to vary somewhat seasonally. During the southern summer, bigeye appear to be displaced farther south along with an associated displacement of warmer water. A pocket of bigeye seems to persist in the area bounded by approximately lat. 15°-30°S and long. 75°-95°W through the year.

The next most dominant species in terms of extent of distribution, but not necessarily in terms of catch, is albacore. Except in a few rare instances albacore are taken by longline in the western Pacific only south of about lat. 5°S, probably in waters of the South Equatorial Current. This species is consistently dominant in the catch south of lat. 15°S and west of long. 105°W. During the first and fourth quarters of the year, the southern summer, when warm waters extend farther south, the northern edge of the albacore distribution is displaced southerly to about lat. 15°S. During the southern winter (second and third quarter) their distribution extends more northerly to beyond lat. 10°S.

Yellowfin tuna are the next most important dominant species of tuna in terms of extent of distribution. This species is the second most important tuna captured in the eastern Pacific in terms of weight landed. The extent of their distribution in terms of dominant species is much more restricted than bigeye and albacore. Yellowfin are dominant in a narrow band throughout the year between lat. 5°N and 15°N. They also appear sporadically as the dominant species in the southern hemisphere off northern Peru.

Very small quantities of southern bluefin are captured in the eastern Pacific Ocean, and in only two areas do they appear as the dominant species (Fig. 13d). Their occurence as the dominant species at about lat. 40°S is to the south of all other species of tuna and billfish shown in the figures.

The billfishes are generally more dominant in the inshore areas than are the tunas, especially north of the equator.

Of the billfishes the striped marlin is the most dominant. During the first and second quarters they are dominant in the north, in the area west of long. 105°W and north of lat. 15°N. This area of dominance appears to expand in all directions in the third and fourth quarters. In the southern area they are more dominant during the first and second quarters, occuring in the waters off Ecuador and northern Peru as far as long. 105°W. Their dominance diminishes remarkably during the third and fourth quarters when their few dominant areas appear generally to be farther offshore.

The sailfish show a very consistent pattern as the dominant species during all four quarters within about 500 miles of the coast between lat 20°N and the equator.

Swordfish occur as the dominant species in only a single 5-degree area off Baja California during the first and fourth quarters.

Generally tunas are the more dominant species of the high seas westward of a line paralleling the coast at about 600-1000 miles offshore whereas billfish are dominant to the east of this line.

Billfishes

To examine more closely the distribution of dominant species of billfish only, we have prepared Figure 14.

The distribution of dominant species can be conveniently broken into four general areas. In the inshore area, within about 500 miles of the coast, between lat. 20°N and the equator, sailfish are dominant throughout the year. Even when included with tunas (Fig. 13) the sailfish remain dominant.

In the offshore area between about lat. 10°N and

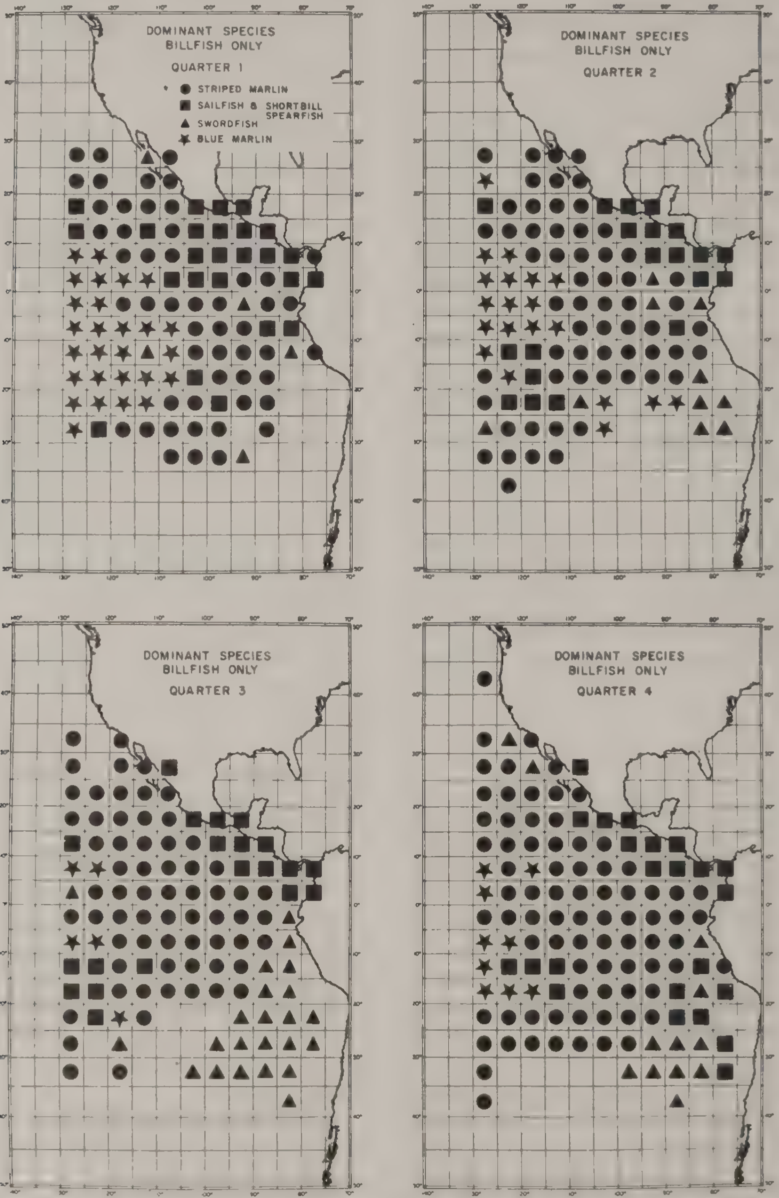
DOMINANT SPECIES
BILLFISH ONLY
QUARTER 1
● STRIPED MARLIN
■ SAILFISH & SHORTBILL SPEARFISH
▲ SWORDFISH
★ BLUE MARLIN
DOMINANT SPECIES
BILLFISH ONLY
QUARTER 2
DOMINANT SPECIES
BILLFISH ONLY
QUARTER 3
DOMINANT SPECIES
BILLFISH ONLY
QUARTER 4

Figure 14.—Dominant species of billfish only in the eastern Pacific by quarters, averaged for the years 1956-1970, by 5-degree areas. **a.** First quarter. **b.** Second quarter. **c.** Third quarter. **d.** Fourth quarter.

10°S, blue marlin are generally the dominant species of billfish. Their eastward extension into the eastern Pacific reaches to about long. 105°W during the first quarter, decreasing to about long 110°W during the second quarter and to long. 120°W by the end of the third quarter. During the fourth quarter, blue marlin appear to become dominant again in a more easterly direction. They are never the dominant species near shore in the eastern Pacific. When compared with tuna, bigeye generally replace the blue marlin as the dominant species in this offshore area.

In the intervening area, which is by far the largest, striped marlin are generally the dominant species, although shortbill spearfish occasionally are dominant. Striped marlin therefore appear to separate the inshore sailfish stock from the offshore blue marlin stock. When compared with tuna, striped marlin remain as the dominant species north of about lat. 15°N, but in the central and lower latitudes are generally replaced as the dominant species by bigeye and albacore tuna.

In the southeastern, inshore area, swordfish are dominant. From a small area off northern Peru in the first quarter, their dominance appears to extend in a southwesterly direction. By the third quarter they are the dominant species of billfish to as far south as lat. 40°S and west to long. 105°W. This area begins to contract to the northeast during the fourth quarter. When tuna are included with billfish, bigeye appear to replace swordfish as the dominant species.

Trends in Relative Apparent Abundance

Because of the wide distribution of fishes and the fact that they cannot be observed in the sea it is impossible to estimate their real abundance by counting them. In order to detect relative changes in the abundance of marine fishes, the catch per unit of effort exerted is used as an index of such abundance. For billfish the index of abundance used in this analysis is the catch by species per 1,000 hooks set. Two important factors can affect the use of catch per unit as an index of abundance. First it is influenced by changes in the availability of the fish themselves and changes in their vulnerability to capture. Secondly, competition of the fish for the hook can bias estimates of abundance in a multiple-species fishery such as the longline fishery.

With respect to the first source of error, if one examines a series of data sufficiently long, the variability in availability and vulnerability tends to balance out. We have not attempted to correct for the latter source of error. Catch per effort by quarter, year, and area are discussed below for striped marlin, blue marlin, sailfish and swordfish.

To facilitate the analysis of catch rates, Kume and Joseph (1969a) divided the eastern Pacific east of 130°W into areas based on the geographical expansion of the fishery. These areas have been renumbered for the present analysis and are shown in Figure 1.

Striped Marlin

The overall catch rate for striped marlin in the eastern Pacific trended upward from 1956 to about 1965; it decreased during the following 2 yr, but during 1968 increased to its highest level. During 1969 and 1970 it decreased to slightly below the 1966 and 1967 levels.

In order to examine in more detail these trends in the abundance of striped marlin we have grouped data into areas in which effort has been consistently expended for an extended time period. We show trends in catch rates for three such areas (Fig. 15).

The lower panel of Figure 15 shows the catch per thousand hooks for the older, equatorial marlin grounds which include areas 9, 11, and 12 of Figure 1. The fishery for striped marlin in this area developed during 1958 and has continued since. Catch rates during the early years were low, less than 2 fish/1,000 hooks. These increased progressively until about 1965 when they reached a high of about 5.5 fish/1,000 hooks. Since then they have exhibited a downward trend to a level of about 2 fish/1,000 hooks during 1969-1970. A great deal of quarterly variability is evident but it does not appear to exhibit any consistent pattern. Though effort does vary among quarters, there again does not appear to be any consistent pattern; the same general levels of effort have been exerted during recent years.

Catch rates for areas 3, 5, and 6, the northern inshore marlin grounds, are shown in the middle panel of Figure 15. The fishery for striped marlin in this region began during 1963. At that time hook rates were quite high, about 14 fish/1,000 hooks. During 1964-1965 they decreased to about 10.5 fish/1,000 hooks. This was followed by an increase to about 12 fish/1,000 hooks, and catch rate has remained at about that level. The magnitude of variability in the quarterly catch of striped marlin in

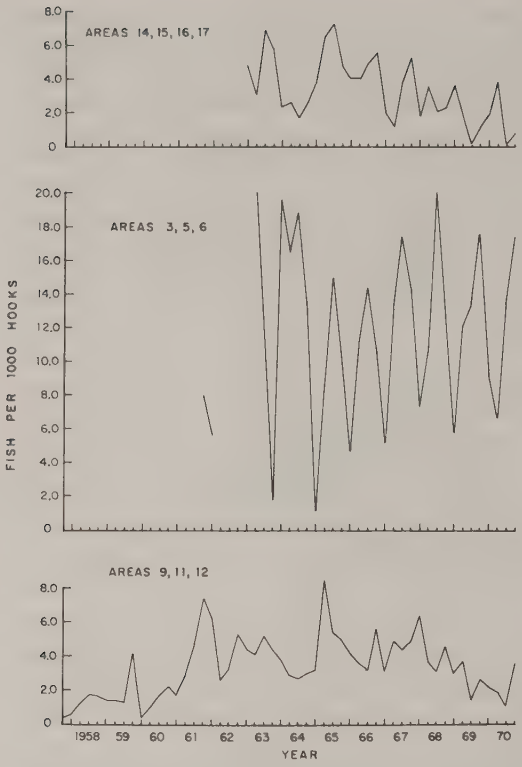

Figure 15.—Quarterly hook rates expressed as number of fish per 1,000 hooks for striped marlin for three major fishing areas in the eastern Pacific Ocean.

this area is great. In a single year quarterly rates have varied by as much as a factor of 15. This variability seems to follow a consistent pattern. Prior to 1969 the first quarter exhibited the lowest abundance while the third quarter exhibited the highest. During the last 2 yr, 1969 and 1970, the peak catch rate shifted to the fourth quarter.

Areas 14, 15, 16, and 17 of Figure 1 are used to represent conditons on the southern striped marlin grounds. The fishery developed during 1962-1963 and since that time has supported a significant share of the longline catch of marlin from the eastern Pacific. Peak catch rates were experienced in this area during 1965 when about 5.5 fish/1,000 hooks were taken. The index of abundance has declined steadily since that time to the present level of about 1.8 fish/1,000 hooks.

These data suggest that the apparent abundance of marlin on the equatorial and southern grounds has decreased to about one-third of its highest level. Apparent abundance on the northern grounds has remained nearly constant since 1965, perhaps increasing very slightly. When all areas in the eastern Pacific are pooled, the catch rate of striped marlin reflects no consistent increasing or decreasing trends since about 1965.

The total catch of this species from the eastern Pacific increased, with increasing effort, to about 270,000 fish by 1964 (Fig. 6). It decreased to about 225,000 fish during 1965 and remained at that level during 1966 and 1967. In 1968 it increased sharply to an all-time high of about 337,000 fish but decreased thereafter to a level of about 180,000 fish by 1970.

It is difficult to interpret these catch statistical data in terms of the effect that fishing may be having upon abundance and productivity because the striped marlin of the eastern Pacific most likely form part of a larger stock in waters to the west. In order to make such a meaningful stock assessment analysis for striped marlin, it would be necessary to examine the dynamics of the stocks over a much wider range of the fishery.

Blue Marlin

Blue marlin have been taken in the Japanese longline fishery since it first began operating in the Pacific, east of long. 130°W, in 1956. Catches of this species are primarily centered in the area lying between lat. 10°N and 10°S and west of about long. 100°W. To examine trends in apparent abundance, catch rates from areas 7, 10, 11, and 13 have been pooled and are shown by quarters in Figure 16. These areas were chosen because a time series of effort extending back to the early years of the fishery are available, and such data should provide a useful index of relative abundance.

During the late 1950's, catch rates for blue marlin varied around 3 fish/1,000 hooks. Up to about 1963, the fishery was very seasonal; the first quarter showed the highest abundance, reaching 5 fish/1,000 hooks at times, and the third quarter showed the lowest abundance dropping to nearly 1 fish/1,000 hooks at times.

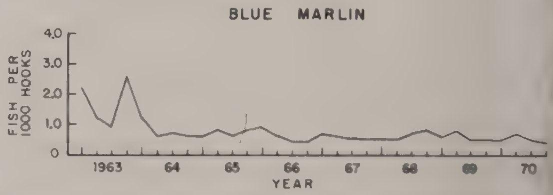

Figure 16.—Quarterly hook rate of blue marlin expressed as catch in numbers per 1,000 hooks for areas 7, 10, 11, and 13 combined.

Abundance began to decline in about 1960 and continued to do so until 1964-1965 when it reached about 0.8 fish/1,000 hooks. By 1966, abundance had dropped to about 0.5 fish/1,000 hooks and has fluctuated about that level since.

Since about 1963 the fishery has not exhibited the marked seasonal pattern which it had prior to that time.

An examination of the catch statistics in terms of numbers of blue marlin (Fig. 6) shows the catch increasing to approximately 75,000 in 1963 in proportion to an increasing effort. By 1966, catches decreased to about 22,000 fish and have continued to fluctuate about that level.

From the earlier analysis (p. 317-318) it seems likely that blue marlin of the eastern Pacific represent the eastern portion of a much larger population whose center lies west of long. 130°W. Therefore it would not be valid to attempt to explain catches and catch rates in the eastern Pacific in terms of effort generated in the eastern Pacific only.

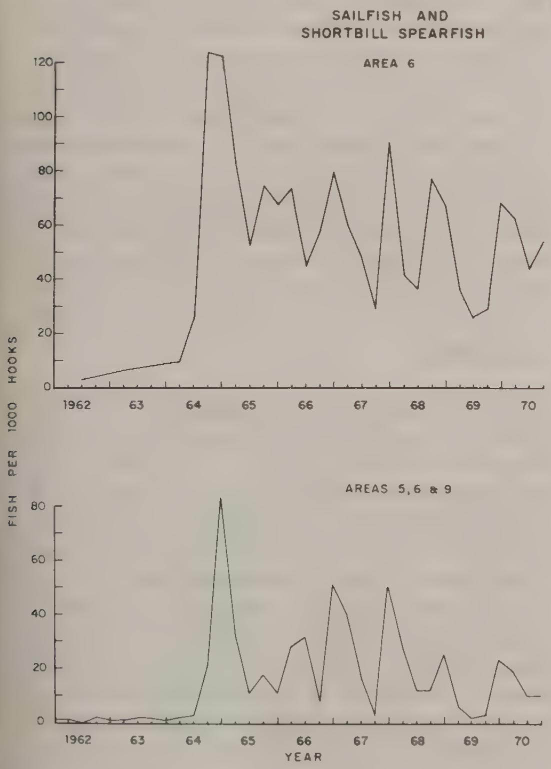

Figure 17.—Quarterly hook rate of sailfish expressed as number of fish per 1,000 hooks. Upper panel area 6, lower panel areas 5, 6, and 9 pooled.

Black Marlin

Catches of black marlin are so low in the eastern Pacific that it is of little value to analyze indices of abundance for this species. Catches increased from about 500 fish in 1956-1958 to about 4,000 fish in 1963 (Fig. 6). Since that time, catches have fluctuated around 4,000 fish, the highest being 4,200 fish in 1969.

Sailfish

It has been mentioned previously that sailfish and shortbill spearfish are not differentiated in the catch statistics of the Japanese longline fishery. Data are available, however, from selected cruises which can be utilized to show the relative distribution of the two species (Fig. 12). It can be noted from Figure 12 and Figure 1 that in areas 5, 6, and 9, shortbill spearfish are not taken, only sailfish. Therefore areas 5, 6, and 9 can be used to represent changes in the indices of abundance. In fact, of the total catch of sailfish and shortbill spearfish, about 80% is comprised of sailfish from areas 5, 6, and 9.

In Figure 17, the catch of sailfish per 1,000 hooks is shown in two groupings. In the lower panel, quarterly catch rates are pooled for areas 5, 6, and 9, where most of the sailfish from the eastern Pacific are caught. In the upper panel, catch rates for area 6, the center of highest sailfish abundance, are shown separately.

In the pooled area substantial effort was not generated on the sailfish grounds until about 1964. By the first quarter of 1965 the catch rate was at the highest observed level, about 83 fish/1,000 hooks. The annual average abundance for 1965 was also the highest observed for the series of years shown, about 32 fish/1,000 hooks. This decreased to about 20 fish/1,000 hooks during 1966-1968, and during 1969 and 1970 dropped to about 11 fish/1,000 hooks. This latter is about one-third the highest value at the outset of the fishery.

The trends in apparent abundance of sailfish in area 6 (upper panel, Figure 17) are similar to the trends for the pooled areas; however, the decline in abundance in recent years has not been as great in area 6. When the fishery first developed on a substantial scale in area 6, the annual catch rate was about 95 fish/1,000 hooks. This decreased rapidly until by 1967 it was about 58 fish/1,000 hooks. Since 1968 it has fluctuated around 53 fish/1,000 hooks.

The total catch in numbers of sailfish and shortbill spearfish combined is shown in Figure 6. The catch increased rapidly from 1962 to 1965 when it reached a peak of nearly 425,000 fish. It has fluctuated greatly since then but has shown a general decline. Because these catch figures represent two species and are for the entire eastern Pacific they might mask any significant trends in catches of sailfish on the primary grounds. Therefore we have computed sailfish catches for areas 5, 6, and 9 combined, and for area 6 separately.

The following table shows catches in thousands of fish:

Area	1964	1965	1966	1967	1968	1969	1970
6	28.6	329.9	173.6	131.3	208.9	72.7	100.5
5+6+9	53.1	366.0	199.7	245.4	359.7	149.8	210.1

Catches from the pooled areas (5, 6, and 9) shown in the table seem to follow rather closely the trend in catches for the entire eastern Pacific. However it appears that in area 6 catches have declined rather sharply. For example the 1970 catch for area 6 is less than a third of what it was in 1965, whereas the 1970 catch for areas 5, 6, and 9 combined is about two-thirds of the 1965 catch from the same areas.

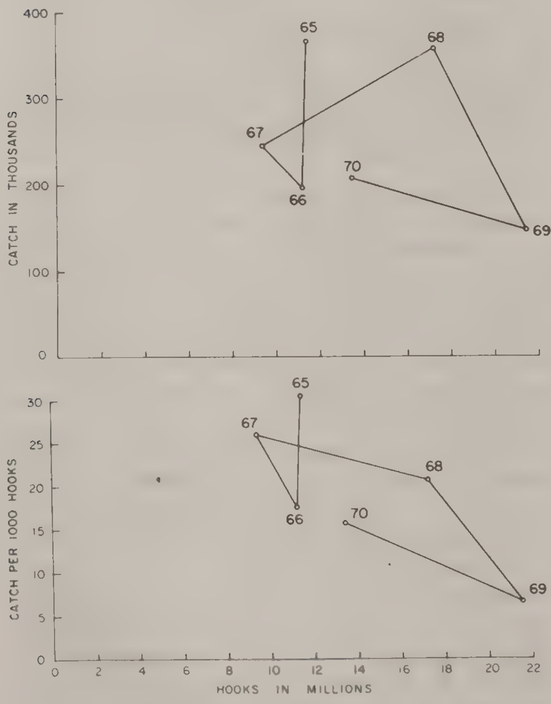

Figure 18.—Relationship between catch in numbers of fish, catch per 1,000 hooks and effort in millions of hooks for sailfish in areas 5, 6, and 9, 1965-1970.

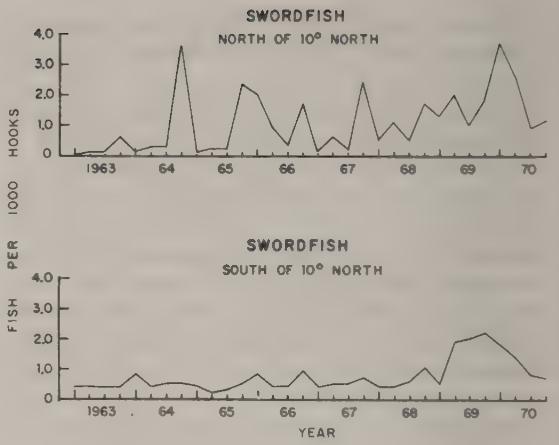

Figure 19.—Quarterly hook rate of swordfish expressed as catch in numbers per 1,000 hooks, for areas north and south of long. 10°N.

The relationship between catch, effort, and catch per effort for sailfish taken during 1965-1970 in areas 5, 6, and 9 is shown in Figure 18. In the lower panel of the figure a negative relationship is evident between catch per effort and effort. This figure suggests, as is expected, that increasing effort will likely result in reduced catch rates. In the upper panel no clear relationship is apparent between catch and effort. Catch for the years 1956-1970 fluctuates about some average which is independent of fishing effort. This would suggest that catches would not be expected to increase on the average as effort is increased.

Swordfish

For the purposes of examing trends in abundance catches of swordfish (which occur throughout the eastern Pacific but are concentrated in the north in area 2 and in the south in areas 9, 12, and part of 18) have been divided into two groups, one north of lat. 10°N and the other south of lat. 10°N. The catch rate may be somewhat confusing in that the longliners have fished at night, utilizing squid as bait, on the northern swordfish grounds since 1964. Night fishing also most likely takes place on the southern grounds but we have no data on this. This form of fishing increases catch rates by a factor of two on the average.

In Figure 19 the number of swordfish caught per 1,000 hooks is shown for the area north of lat. 10°N (upper panel) and for the area south of lat. 10°N (lower panel) by quarters, 1963-1970. Hook rates on the average are lower in the south than in the north, even after allowing for differences in efficiency due to setting time. Catch rates also seem to be more variable in the north than in the south. There is a marked seasonal pattern, with highest hook rates generally during the fourth quarter in the north but such a pattern is not evident in the south. The fourth quarter peaks do not appear to be related to corresponding variations in fishing effort and vessel concentration, but likely represent changes in catchability.

Slight upward trends in catch rates are detectable in both the north and the south, probably due to increased efficiency as a result of increased night sets and concentration on the more productive swordfish grounds.

The catch of swordfish (Fig. 6) on the average has increased steadily since 1956. The peak year was 1969 when about 112,000 swordfish were taken and effort was at a maximum. Both effort and catch decreased in 1970 but catch per effort in the north did not decrease. In the south, a decrease in catch per effort was noted during 1970.

Before catch per effort can be used as a very good indicator of swordfish abundance it will be necessary to adjust all data for the effect of night sets. It is also essential that the amounts captured by coastal fisheries (which may be substantial) be accounted for in the analysis; for example during 1970, nearly one million pounds of swordfish were taken in the California surface fishery. Without the inclusion of such data it is useless to speculate on interpretation of the data represented herein as far as stock assessment analyses are concerned.

CONCLUSIONS AND RECOMMENDATIONS

The importance of billfishes to man has been abundantly demonstrated and documented. Large and important longline fisheries exist for billfishes throughout the oceans of the world, especially in the eastern Pacific Ocean. Important sport fisheries upon which the economy of local communities depend exist for billfishes, not to mention the important recreational aspects of the fisheries to a large segment of the population. Many subsistence fisheries depend upon billfishes as their sole supply of raw material.

To insure rational utilization of this resource (rational in this sense implies some sort of sustained harvests for all categories of use) the effect of man's exploitation on subsequent recruitment and average size of the stock needs to be analyzed. This has not been done for the billfishes of the eastern Pacific Ocean, nor for the billfish of the Pacific Ocean generally, nor for any other ocean to our knowledge.

In this paper we were unable to comment, except in a very general way for some species, on the condition of the billfish stocks in the eastern Pacific. The reasons for this were primarily due to the fact that the statistical data were limited, the area of study extended to only long. 130°W, and vital statistics concerning the population were not available.

If it is the desire of mankind to manage the fisheries for billfish so as to insure sustained harvests, at whatever level is deemed desirable, then certain basic data and studies are needed. Some idea of the relative distribution of the population under study needs to be established. If the population is divided into distinct units on the basis of biological characteristics and/or distributional characteristics of the fish and fishery, then this must be determined; these units cannot be established on the basis of jurisdictional limits. For each of the population units, estimates of the total catch are needed; these should include catches from commercial, sport, or any other fishery which might take meaningful quantities of billfish. Some idea of fishing mortality is required; this is generally estimated as a function of fishing effort. Therefore estimates of fishing effort for a major share of the catch are needed as an index. The size composition of the catch by strata of time and area are useful for conducting studies of growth rates and mortality rates, and are a necessary ingredient to the determination of the relationship between stock size and subsequent recruitment. A sampling program to obtain such measurements should include samples from all important fisheries.

From the discussions presented in this report it is clear that all six of the billfish which occur in the eastern Pacific Ocean are found all the way across the Pacific. The longline fishery which takes these six species exploits nearly every 5-degree square over the range of each species. Evidence from billfish tagging demonstrates that some species undergo extensive migration in the Pacific Ocean (Mather, 1969; James L. Squire, Jr. pers. comm.). Such migrations have been demonstrated in other oceans as well (Mather, 1969).

It is clear that the scope of billfish studies needs to be extended throughout the Pacific Ocean. Such studies must include all important fisheries. At the present time integrated broad-scale studies of billfish have not been conducted, nor are they apparently underway.

This situation may be due in part to the lack of a well-defined set of goals or objectives for billfish research. Such a set of goals would necessarily have to be responsive to the different needs of the various user sectors of the fishery for billfish. To define these objectives and goals there needs to be an international platform for the discussion of these goals and objectives, a platform in which the proper questions can be framed and asked. By asking the proper questions, such goals and objectives, which are responsive to the needs of all individuals, communities, and nations, can be formulated.

There are a number of platforms which can serve as a mechanism for formulating an integrated approach to billfish studies but it would indeed be unfortunate if we did not take advantage of this Symposium to discuss the subject.

ACKNOWLEDGMENTS

The authors wish to express their gratitude to the Director of the Far Seas Fisheries Research Laboratory, Osamu Kibesaki, for allowing us to utilize certain of their preliminary data. Special gratitude is also extended to Akira Suda and Susumu Kume of the same laboratory for their assistance in preparing the data for analysis.

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Billfish Fishery of Taiwan

H.C. HUANG[1]

ABSTRACT

Billfish landings made by Taiwan fishing vessels from 1962 to 1971 were analyzed and described briefly. Billfishes are commercially harvested in Taiwan by deep-sea and inshore longline fisheries and the harpoon fishery. The important species caught include swordfish, striped marlin, blue marlin, black marlin, and sailfish. The deep-sea longline fishery has developed rapidly since 1954 and the landings of billfishes have increased accordingly. Fishing operations have covered the major fishing grounds of the Pacific, Indian, and Atlantic Oceans. The inshore longline fishery still confines its activities to waters around Taiwan; billfish landings made by this fishery fluctuate annually.

Billfishes are commercially harvested in Taiwan by the deep-sea and inshore fisheries. In the deep-sea fishery, the longline is used exclusively to catch tunas, as well as billfishes. The principal gears used in the inshore fisheries to take tunas, billfishes, and other large pelagic fishes are the longline and harpoon. Gill nets and set nets are also used occasionally to capture billfishes that enter the coastal and inshore waters of Taiwan. Longline fishing was introduced in Taiwan by Japanese fishermen in 1913. For many years after its introduction longlining was limited to the coastal and offshore waters of Taiwan. From 1913 until 1954, the fleet consisted mostly of vessels of less than 50 tons. Since 1954, the size of the fleet, as well as the average tonnage of vessels, has increased rapidly. Vessels over 50 tons, classified as "deep-sea longliners" by the Taiwan Fisheries Bureau, have expanded their operations from the traditional waters off Taiwan to waters as far distant as the Indian, South Pacific, and Atlantic Oceans. Vessels of less than 50 tons, classified as "inshore longliners," still remain in the offshore waters around Taiwan.

In 1962, there were only 42 deep-sea longliners totaling 6,634 gross tons in Taiwan, but by 1971 the fleet had increased to 457 vessels and totaled 99,217 gross tons. In order to meet the practical requirements of fishing in distant waters, many foreign ports located close to the important fishing grounds have been used since 1954 as overseas supply bases for the longliners. At these overseas bases the longliners are able to replenish supplies, effect repairs, and sell the fish catch locally or transship it for export. The tremendous development of this deep-sea fishery is attributed to the growing profit of the industry, as well as the encouragement given by the government.

The inshore longline fishery has contained between 600 and 800 vessels since 1962. The vessels range in size from 5 to 50 tons, with the most typical size at about 30 tons. From time to time, the inshore longline fleet shifts from one fishery to another.

The harpoon fishery for billfishes was introduced in Kao-hsiung, a southern port of Taiwan, by the Japanese in 1913. Later, the fishery gradually expanded from Kao-hsiung along the east coast of Taiwan to Keelung in the north, and the fishery covered the whole of the Kuroshio Current area near Taiwan. The harpoon fishery has been limited to waters about 30 miles from home port and the fleet has kept its size between 150 and 350 vessels from 1962 to 1971.

SPECIES OF BILLFISHES

The principal species of billfishes exploited by the Taiwan fisheries include:

1. Swordfish, *Xiphias gladius*.

In Chinese the swordfish is called "Chien Ch'i

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[1] Taiwan Fisheries Bureau, 8, 1st Section, Chung Hsiao East Road, Taipei, Taiwan.

Table 1.—Annual landings (in metric tons) of billfish made by the various fisheries in Taiwan, 1962-1971.

Year	Total	Deep-sea longline	Inshore longline	Harpooning	Other
	(metric tons)				
1962	9,027	1,501	4,716	2,648	162
1963	10,915	2,088	5,746	2,864	217
1964	9,167	1,973	4,492	2,516	186
1965	8,667	1,655	4,361	2,344	307
1966	10,404	2,654	4,819	2,618	313
1967	11,297	3,698	5,101	1,995	503
1968	16,012	6,363	6,961	2,260	428
1969	17,994	8,691	6,998	1,995	310
1970	15,502	8,060	5,203	1,981	258
1971	16,573	8,760	5,640	1,865	308

Yü’’; also called ‘‘Tinmankhū’’ or ‘‘Ki Hi Khū’’ by local fishermen. Swordfish are pelagic, circumtropical fish of worldwide distribution. In Taiwan, swordfish are caught in waters along the east and south coasts, mainly by harpoon and longline gear. Occasionally, swordfish are taken by gill nets during the northeast monsoon season from October to April. During the fishing season, swordfish often swim and bask near the water surface, exposing the caudal and dorsal fins and sometimes jumping out of the water. These fish are not easily disturbed, and with these habits, swordfish are easily spotted by the harpoon fishermen. The swordfish grows to a size of 4.5 m in length and over 500 kg in weight. Fish weighing 140 to 180 kg are considered large. In Taiwan the swordfish is valued as an excellent food fish and is consumed as raw fish (sashimi) or fried with salt.

2. Striped marlin, *Tetrapturus audax*.

In Chinese the striped marlin is called ‘‘Chêng Ch’i Yü’’; also called ‘‘An-bah Ki Hi’’ by local fishermen. Striped marlin are found throughout the tropical Indo-Pacific waters. In Taiwan this species occurs around the island throughout the year and is caught mostly by the harpoon and longline fisheries, principally in the spring and summer months in the Kuroshio Current area located along the east coast of Taiwan. This species usually swims near the surface in small groups with their caudal fins exposed. Fish weighing 100 kg are occasionally caught; however, fish of 40 to 60 kg are most common in the Taiwan catch. It is hypothesized that striped marlin of this population spawn in the South China Sea near Taiwan during the month of May. After spawning striped marlin migrate northward.

The so-called ‘‘Taiwan striped marlin’’, *Makaira formosana* (Hirasaka and Nakamura), is considered to be the juvenile of *T. audax.*

The flesh of striped marlin is reddish and rich in flavor; the species is considered an excellent food fish by the Chinese people.

3. Blue marlin, *Makaira nigricans*.

In Chinese the blue marlin is called ‘‘Hêi-pi Ch’i Yü’’; also called ‘‘O-phê ki Hi’’ by local fishermen. The blue marlin is an oceanic species which is widely distributed in the Pacific and Indian Oceans. In Taiwan, fishing for blue marlin by longline and harpoon is carried out year-round; however, effort is concentrated during the months of February, March, and September. It is known that blue marlin spawn in June in waters east of Taiwan. This species reaches 3 m in length and 500 kg in weight. Like the striped marlin, the blue marlin is considered a delicacy by the Chinese people.

4. Black marlin, *Makaira indica*.

In Chinese the black marlin is called ‘‘Pai-Pi Ch’i Yü’’; also called ‘‘Kȳau-sh’ih-á’’ or Péh-phê Ki Hi’’ by local fishermen. Black marlin are found throughout the tropical and subtropical waters of

Table 2.—Annual landings (in metric tons) of billfishes by species in Taiwan, 1962-1971.

Year	Total	Swordfish	Striped marlin	Blue marlin	Black marlin	Sailfish[1]
	(metric tons)					
1962	9,027	774	761	1,193	2,567	3,732
1963	10,915	723	1,188	1,379	2,656	4,969
1964	9,167	584	1,000	1,808	2,563	3,212
1965	8,667	540	1,001	2,127	2,323	2,676
1966	10,404	885	1,191	2,031	3,163	3,134
1967	11,297	1,258	1,472	2,658	2,390	3,519
1968	16,012	1,950	1,648	4,407	2,869	5,138
1969	17,994	2,643	2,747	4,525	3,409	4,670
1970	15,502	2,369	2,522	4,412	2,675	3,524
1971	16,573	2,543	1,796	4,261	3,616	4,357

[1] Other unidentified marlins are included under ‘‘Sailfish.’’

the Pacific and Indian Oceans. Off Taiwan, black marlin are taken along the east coast by the longline and harpoon fisheries. This species is caught year-round; however, best catches are made from October to April. Black marlin are reported to spawn in the offshore waters of Taiwan from August to October. It is one of the largest of the marlins caught in Taiwan. The species is also considered a good food fish in Taiwan.

5. Sailfish, *Istiophorus platypterus*.

In Chinese the sailfish is called "Yü San Ch'i Yü"; also called "Hō Soan Ki Hi" or "Pua Hō Soan-á" by local fishermen. Sailfish enter the Taiwan inshore waters more often than any other species of billfish. In Taiwan sailfish are caught year-round along the entire coast of the island by longline, harpoon, and other fishing gear. From April to July and from October to December, the fishermen catch large numbers of sailfish in the Bashi Channel located near southern Taiwan. During the fishing season, sailfish often occur in schools in the Kuroshio Current.

Sailfish have been observed to swim with their high dorsal fins exposed and chasing sardine, squid, or other smaller prey. Fishermen find it fairly easy to harpoon sailfish; however, once harpooned the sailfish will leap and twist in an effort to shake loose.

Adult sailfish with mature gonads have been reported by fishermen in southern Taiwan waters from April through August. This species grows to 2 m in length and 60 kg in weight. In comparison with other species, sailfish are not considered a good food fish by the Chinese people.

Table 3.—Annual landings (in metric tons) of billfish by Taiwan deep-sea longliners by ocean, 1967-1971.

Year	Area	Total	Swordfish	Striped marlin	Blue marlin	Black marlin	Sailfish	Other marlin
					(metric tons)			
1967	Pacific	935	126	63	346	50	94	256
	Indian	2,047	275	665	704	236	134	33
	Atlantic	716	177	155	227	28	121	8
	Subtotal	3,698	578	883	1,277	314	349	297
1968	Pacific	854	65	119	594	54	22	—
	Indian	3,622	616	783	1,065	616	542	—
	Atlantic	1,887	494	206	506	10	671	—
	Subtotal	6,363	1,175	1,108	2,165	680	1,235	—
1969	Pacific	1,180	108	134	565	191	71	111
	Indian	4,384	801	1,373	1,258	572	190	190
	Atlantic	3,127	883	478	846	258	478	184
	Subtotal	8,691	1,792	1,985	2,669	1,021	739	485
1970	Pacific	1,621	188	269	646	143	127	248
	Indian	3,920	641	1,140	997	499	213	430
	Atlantic	2,519	630	429	687	143	458	172
	Subtotal	8,060	1,459	1,838	2,330	785	798	850
1971	Pacific	1,695	247	230	690	300	71	157
	Indian	4,614	580	598	1,144	687	283	1,322
	Atlantic	2,451	721	383	492	174	301	380
	Subtotal	8,760	1,548	1,211	2,326	1,161	655	1,859
	Total	35,572	6,552	7,025	10,767	3,961	3,776	3,491

BILLFISH LANDINGS

The annual landings of billfishes made by Taiwan fisheries from 1962 to 1971 show an increase corresponding with the increase of the total Taiwan fisheries production (Tables 1 and 2). The landings showed a steady increase from 9,027 metric tons in 1962 to 16,573 metric tons in 1971—a 10-year average rate of increase of 8.4%. The billfish landings as a percentage of the total fish production, however, have not changed significantly during this period, the increase ranging from 2.4% to 3.1%.

By species, the landings of swordfish ranged from 540 to 2,643 metric tons and peaked in 1969; striped marlin from 761 to 2,747 metric tons and peaked in 1969; blue marlin from 1,193 to 4,525 metric tons and peaked in 1969; black marlin from 2,323 to 3,616 metric tons and peaked in 1971; combined sailfish and other unidentified marlins from 2,676 to 5,138 metric tons and peaked in 1968. Among these species, swordfish and blue marlin showed greater fluctuations in annual landings than any other species.

Prior to 1965, landings made by the inshore longliners ranked first followed by harpooning and the deep-sea longliners. After 1965, the landings of the deep-sea longliners increased rapidly, and since 1968 the deep-sea longliners have surpassed the inshore longliners. The landings of the deep-sea longline fishery were only 1,501 metric tons in 1962, increased slightly to 2,654 metric tons in 1966, but thereafter the fishery developed rapidly. As a result, the deep-sea fishery landings of billfishes jumped to 6,363 metric tons in 1968 and reached a record high of 8,760 metric tons in 1971. Landings of the harpoon fishery declined slightly from 2,648 metric tons in 1962 to 1,865 metric tons in 1971; the decrease occurred despite an increase in fishing effort. The inshore longline fishery showed a slight increase in annual landings from 4,361 metric tons in 1965 to 6,998 metric tons in 1969.

In 1967 the Taiwan Fisheries Bureau initiated a survey of production and marketing in the deep-sea longline fishery, with emphasis placed on the collection of the landing statistics of billfishes, tunas, and other species. As a result of the survey, excellent data are available for fishing effort and catch by species for Taiwan vessels operating throughout the world's oceans.

In a breakdown of billfish landings made by the deep-sea longline fishery from 1967 to 1971, the Indian Ocean ranked first, followed by the Atlantic and the Pacific Oceans (Table 3). The Indian Ocean catches contributed 55% of the yearly total landings of billfishes made in 1967, 57% in 1968, 50% in 1969, 49% in 1970, and 53% in 1971. The annual landings of billfishes from the Atlantic Ocean accounted for 20%, 30%, 36%, 31%, and 28% for the years 1967 to 1971, respectively. The Pacific Ocean catches accounted for 25%, 13%, 14%, 21%, and 19% for the years 1967 to 1971, respectively. The percentage of the various species in the annual billfish landings made by the deep-sea longliners in the three ocean waters during 1967-1971 showed rather large annual fluctuations. The blue marlin was dominant in the Pacific and the Indian Oceans, while in the Atlantic the swordfish was the dominant species.

Tables 1 and 2 show the annual billfish landings by the various fisheries by species from 1962 to 1971. Table 3 shows annual landings of billfishes by the deep-sea longliners by ocean from 1967 to 1971. Table 4 shows the distribution of fishing effort of the Taiwan deep-sea longline fleet from 1967 to 1971.

Table 4.—Distribution of fishing efforts of Taiwan deep-sea longline fleet, 1967-1971.

Year	Number of vessels	Fishing trips			
		Total	Pacific	Indian	Atlantic
1967	254	570	380	169	21
1968	333	1,007	359	467	181
1969	396	1,158	298	576	284
1970	418	1,258	435	539	284
1971	457	[1]1,182	495	409	278

[1] Estimated.

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